COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

April, 1950

Photo by Hedrich-Blessing

Chemical recovery and power generation at a newsprint plant

Current Trends in Fly Ash Recovery

Report of Midwest Power Conference

Conditioning Boiler Water by High-Temperature Sodium Ion-Exchange

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Editorials

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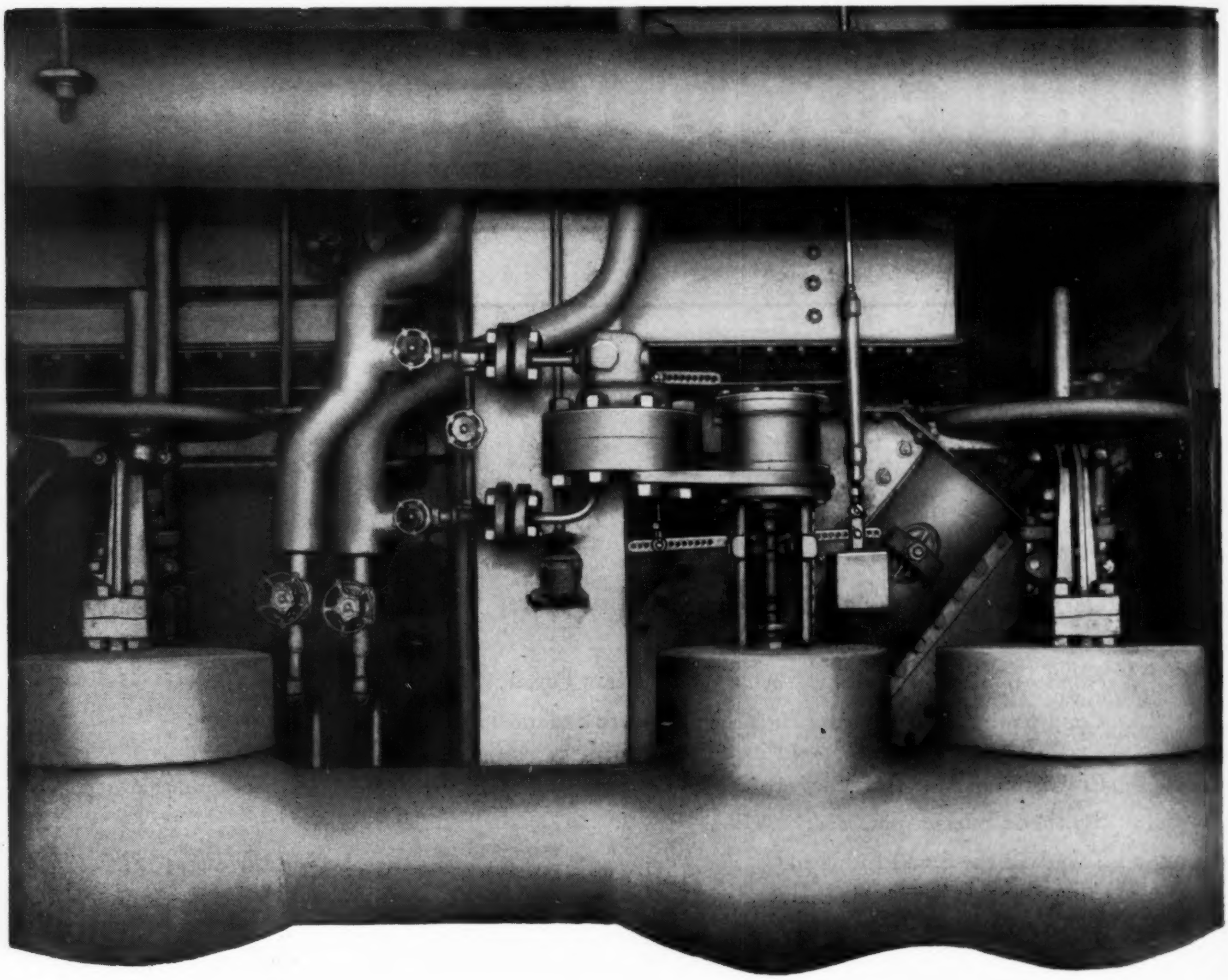


COMBUSTION

Editorials

Industry-College Relationships

Self-evident though it may be that both industry and education benefit from mutual interchange of ideas and personnel, all too often in practice there exists an isolation of the educator and the industrialist. Working in the same world but treading their respective paths of self-interest, both groups allow many problems to solve themselves, as it were, by default. How much better it would be were there more opportunity to see the other side of the fence.

A forward step in the direction just mentioned was taken on March 25 at the "Industry-College Conference" sponsored by the Division on Relations with Industry of the American Society for Engineering Education and Swarthmore College. At this highly successful meeting an outstanding industrial leader cited the benefits to be gained by having more engineering teachers participate in intermittent industrial employment, perhaps during the summer period, or on a consulting basis.

It should be apparent that the professor who shuttles between the shop and the campus is more acutely aware of realistic industrial needs, particularly in terms of effective preparation of young engineers, than the pedant hidden away in some realm of academic fantasy. At the same time, engineering education itself gains by such interchanges, for close contact between colleges and industries can be an effective means of reducing the inevitable lag between industrial practice and "textbook theory." More attention by engineers generally to industry-college relationships will pay big dividends.

Stressing Atmospheric Pollution

Atmospheric pollution, smoke abatement and kindred topics seem to be in the forefront of many engineering programs this spring. A largely attended session, comprising five papers on the subject, highlighted the recent Midwest Power Conference at Chicago. The Federal Government, at the request of President Truman, has sponsored a three-day technical air-pollution conference at Washington, D. C., May 3 to 5. This will comprise seven simultaneous sessions to discuss the subject from the standpoints of meteorology, effect on health, instrumentation, equipment, analytical methods of analysis, legislation, and the effects of air pollution on agriculture. Many scientists, from here and abroad, have accepted invitations to attend.

Following closely on this will be another three-day meeting in Montreal, Canada, on May 22 to 25, under the auspices of the Smoke Prevention Association of America.

One may be inclined to ask: Why all this attention to a matter that has been discussed so often and concerning which so much progress has already been made through legislation, education and improved equipment?

The answer appears to be that accomplishments in the past have largely concerned visible contaminants, such as smoke and fly ash discharged from stacks, whereas gaseous pollution from industrial processes, exhausts from automobiles and dusts from innumerable sources have not yet been completely studied nor effectively brought under control. In fact, we are only just beginning to learn something of their relation to certain natural phenomena. It is further to stimulate basic studies on this phase of the subject, while at the same time sustaining interest in smoke abatement, that such conferences serve a useful purpose.

As Envisaged by Rankine

Periodically it is well for engineers to take a backsight and attempt a re-evaluation of great founders of their profession. One of the real intellectual giants of Nineteenth Century technology was William J. M. Rankine, a professor at the University of Glasgow. Today he is best known for the thermodynamic cycle bearing his name, but he is also the author of at least one of the enduring classics of engineering literature.

"A Manual of the Steam Engine and Other Prime Movers," published initially in 1859 when Rankine was thirty-nine years of age, was the first systematic treatise on the science of thermodynamics. More than that, it exemplified an amazing vision of future steam plant improvements, some of which have been realized only within the last few years. One section is entitled "On the Action of Superheated Steam" and another "Of Binary Vapour Engines." Considering the time at which the book was written and limitations on the art of fabrication, as well as the relatively meager knowledge of metallurgy, it is all the more amazing that the Scottish educator was able to foresee future developments so realistically.

The work of Rankine points to a truth important to all engineers. That is, the significance of vision in engineering activity. Rarely does a technical problem have but one method of approach, and the successful engineer must develop the mental courage to see beyond immediate obstacles to more distant possibilities. William J. M. Rankine symbolized qualities of vision that might well be emulated today.

Current Trends in Fly Ash Recovery

By RICHARD O'MARA
Western Precipitation Corp.

Following a description of the various types of dust separators and collectors, their advantages and disadvantages are reviewed, with particular reference to the physical characteristics of fly ash. The application and efficiencies of mechanical collectors and electrostatic precipitators, separately and in series, are also discussed.

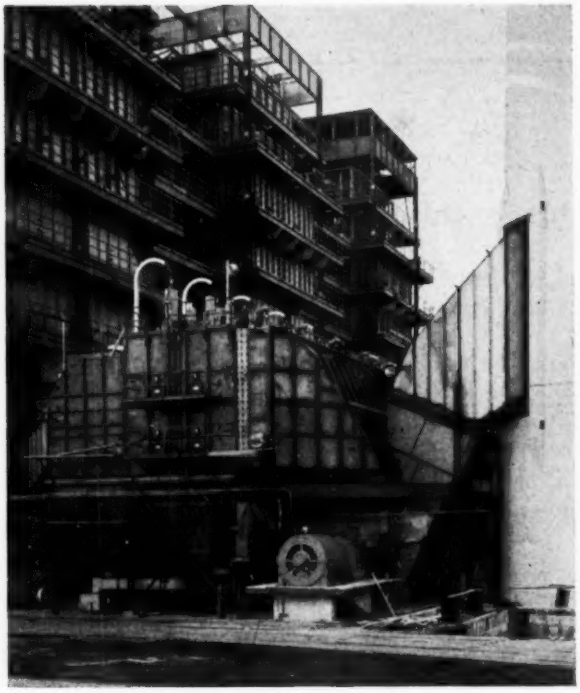


Fig. 1—Mechanical and electrostatic precipitator in series in a post-war central station

THE cleaning of gases has progressed a long way since the early beginnings of the use of coal in England many years ago. Fly ash is recognized as only one of the many kinds of contaminants that cause atmospheric pollution. For many years industry stayed out of trouble by the simple expedient of using a stack. With low velocity, the heavy cinders settled out in the stack base and the ash discharged from the stack was dispersed over a sufficiently wide area to avoid local nuisance.

As early as the Thirteenth Century in England the burning of coal came in for some regulation by the Crown. So far in this country control or regulation of stack emission has been left largely to local governments. Recently, however, the national government has become interested and is apparently embarking on a fairly far-reaching program on atmospheric pollution. Whether or not this will result in regulation on a national scale remains to be seen.

The fly-ash problem is primarily associated with coal-fired boilers, although it should not be overlooked that gas and particularly oil-fired boiler installations can cause certain nuisances in the neighborhood during soot-blowing periods. Some oil-fired plants are equipped with mechanical collectors in a bypass line to the stack so that they can be used during soot blowing. They have proved effective. Many coal-fired boilers are now burning oil and gas, but it is believed that over the long term the economics of coal burning versus gas and oil is likely to change the situation.

Early smoke ordinances were aimed primarily at reducing black smoke and soot and the large cinders that settle relatively close to the plant, whereas more recent ordinances are endeavoring to control the total amount of particulate matter discharged to the atmosphere based on some specified set of conditions in the plant. Combustion control, better furnace design and improved methods of firing coal have largely eliminated smoke. There is little reason for smoke in any modern installation. Large central stations have been awake to the fly-ash problem for many years and have endeavored to install and maintain the best equipment that was available. Different methods of gas cleaning have been investigated and many types installed with various degrees of success. A brief review of these will be given.

Gravitational Separators

The earliest form of gravitational separator used for removing fly ash was to reduce the velocity in the breeching and the stack, thus permitting the large cinders to separate out by gravity and be periodically removed. Cinders also settled out by gravity in various parts of the boiler setting.

Inertia-Type Separators

There are two types of equipment operating on the so-called inertial separating method—the baffle-chamber type and the cyclone type. Under this general heading there would also be included cinder separating fans of various descriptions and louver separators.

As gravity is the acting force in the settling chamber, change of direction of the gas in centrifugal or inertial apparatus causes separation of suspended particles from the gas. This force is directly proportional to the square of the gas velocity and inversely proportional to the radius of curvature of the gas stream. It can be increased or decreased by changing gas velocity or diameter of the separating element.

Baffle-Type Separators

In inertial-type baffle chambers, the gas pass may be approximately parallel to the flow but subjected to sufficient change of direction to cause separation of particles as the gas passes through or around obstructions. This is usually accomplished by making the baffles of such a form that relatively dead pockets are established from which the ash particles can settle into the hopper.

Baffle chambers have the advantage of low draft loss —$^1/_4$ to 1 in. water gage—and are used mostly with natural-draft installations. Their main disadvantage is that they are bulky and sensitive to gas velocity changes and are not effective on small particles. Baffle chambers are sometimes used as primary collectors ahead of more efficient equipment.

Louver-Type Separators

A high-velocity inertial separator that falls between the baffle type and the cyclonic type is the louver in which concentric overlapping conical rings tend to guide the dust into the small end of the cone while the gas passes out along the sides. This has a higher draft loss, somewhere between baffle chambers and cyclonic separators. Little information is available on its practical application with fly ash but it may be assumed that the results would be somewhat proportional to the power input.

Cyclones

In general, in cyclonic separators the gas path involves an outer downward flowing vortex and an inner upward flowing vortex. The most commonly used method of providing vortex flow in cyclones is an involute or tangential type inlet; usually a single inlet. Involute inlets have been used for many years. An alternate method uses helical vanes in the annular space between the collecting tube and the outlet tube to impart a spiral motion to the gas flowing into the tube.

Large diameter cyclones are still in use in some of the older power plant installations. The trend is toward the use of a multiplicity of small-diameter cyclones operating in parallel in conjunction with a single header. Numerous examples of this type of apparatus have been installed since the initial installation of a 9-in. diameter vane-type multiclone at the British Columbia Sugar Refining Company in Vancouver in 1931. This installation gave an efficiency of 85.6 per cent. Multiple tubes of from 24-in. down to 3-in. diameter tubes are now used and, as would be expected, the smaller diameter tubes tend to have higher efficiencies, but there appears to be little advantage in going below 4 to 6 in. diameter. In practice, some of these designs operate with a pressure drop of 2 to 3 in. of water and efficiencies in the range of 80 to 90 per cent.

The advantages are that the separation is dry; there are no moving parts; reasonable efficiency is obtained; and the units are compact and fit well in boiler layouts. Disadvantages are the high draft loss and maintenance. Cyclonic separators by their very nature are subject to a certain amount of erosion but this can be controlled by avoiding high velocities and selecting suitable wear-resistant materials. Some designs provide easily removable and replaceable parts. The chief limitation is the maintenance of the free open passage for gas and dust. The clearances throughout the equipment must be sufficient to prevent clogging from the accumulation of suspended solids. This makes very small diameter collectors more or less impractical for continuous commercial operation.

Skimmers differ from cyclones in that there is no reverse flow double vortex, but only a single vortex with a direct flow through the tube. The concentrated dust is skimmed off at the periphery near the outlet, usually with a small fraction of the gas. Skimmer collectors of equivalent diameters to cyclones have approximately the same efficiencies at equivalent draft loss and have most of the same advantages and disadvantages. In dust separating fans the dust is concentrated in the outer scroll of the fan housing and drawn off, usually with a small portion of the gas.

In either type the heavily dust-laden gas bled from the primary separators is conducted to a secondary separator where the bulk of the dust is removed and the gas then returned to the inlet of the primary separator or vented. This two-stage separation is an added complication with its attendant maintenance problem.

Dust-separating fans have been used as cinder separators, particularly for hog fuel but the trend is toward the use of cyclonic apparatus.

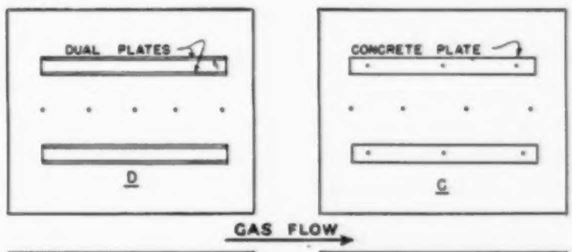


Fig. 2—Outline drawing showing various types of collecting electrodes

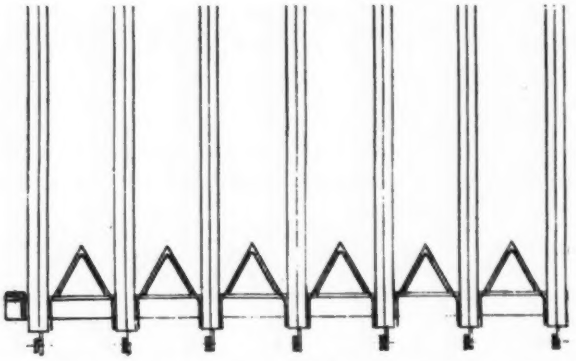


Fig. 3—Outline drawing showing "steeples"

Scrubbers

Scrubbers of various types are available and will effectively remove fly ash, but they are usually attended with high operating cost resulting from high draft loss and water pumping charges. In addition, they introduce serious corrosion problems, not only in the scrubber itself but in the fan which may follow the scrubber and also in the stack. Another drawback is the separation of the fly ash from the water and the subsequent disposal of the sludge. The effluent may also become a problem due to its acidity. Although it is true that dry collectors provide a light dusty material to dispose of, suitable wetting devices are available which will add sufficient moisture to make the ash easily handled.

Filters

Well-designed filters such as simple bag-houses or cloth-covered leaf-type arrangements are available, but pending the development of fabrics that will not deteriorate under high temperature, corrosion or mechanical wear, it is doubtful that filters will be a practical solution to the fly ash problem. Cloths of asbestos fibers and glass fibers offer possibilities and the new synthetic plastic fibers under development may prove interesting in the future. Although high efficiency is obtainable, draft loss is also high and replacement and repair of filter surface and mechanical parts is costly and interferes with continuity of operation.

Ultrasonic Method

The latest addition to the family of dust and fume collectors is the ultrasonic method. This has been investigated for several decades but no industrial progress was made until recently because of the limited capacity of the sound wave generator. Even now with the sources of substantial quantities of sound energy at high frequencies, it does not appear to be very practical for fly ash recovery. With modern high efficiency steam generators the resultant fly ash does not have particularly cohesive properties, although it will agglomerate to some extent; the agglomerates readily redisperse in the gas, making them very difficult to remove in a follow-up collector.

Furthermore, this method is power consuming because of the low efficiency of sonic generation, and the pressure loss through secondary separators following the agglomerating chamber.

Electrical Precipitators

Sixteen years after Dr. Frederick G. Cottrell installed the first satisfactory commercial electrical precipitator, Cottrell electrical precipitation was introduced into the power plant industry with an installation at Detroit in 1923. It has been widely used, particularly for large central stations, since that time.

In principle, this method consists of passing gases through an apparatus consisting of two sets of electrodes electrically insulated from each other between which a static field is maintained at a high electrical potential. One set of electrodes is usually referred to as the high-voltage electrode system. The collecting electrode system is grounded while the high-voltage system is maintained at a negative potential usually in the range from 30,000 to 60,000 volts.

To facilitate electrical discharge, the high-voltage system ordinarily consists of wires or square twisted rods having edges of such radius of curvature as to create a static field sufficiently strong to cause ionization of the gases. The grounded collecting electrodes are made of such configuration as to present a large surface on which the separated material can be collected. A variety of collecting surfaces are available such as single or dual steel plates, wire mesh, graded resistance concrete plates, plates with baffles or pockets and many other forms, used singly or in combination. A few typical examples are shown in Fig. 2.

Space will not permit a detailed discussion of the advantages and disadvantages of various types of collecting surfaces; however, it should be noted that the characteristics of the collecting electrode surface are of importance in minimizing erosion of collected fly ash and re-entrainment in the gas stream as velocity increases. Fly ash will tend to erode off of some types of electrodes much easier than others; for example, smooth collecting electrodes are not particularly satisfactory for fly ash and for a long time graded resistance concrete

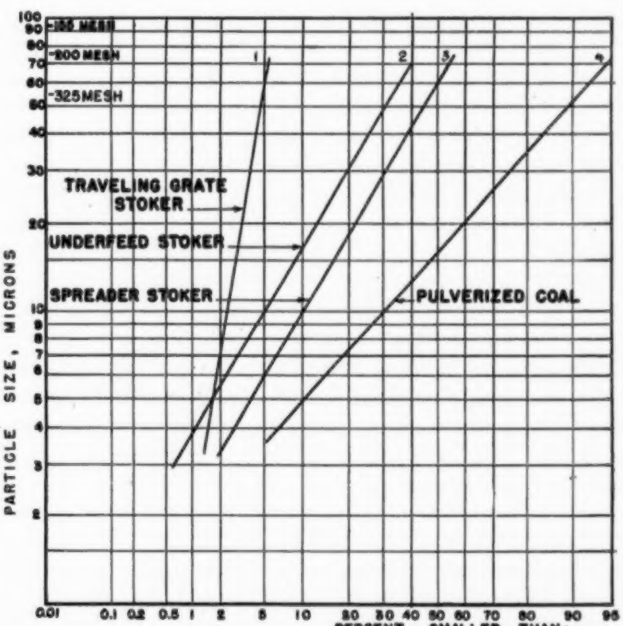


Fig. 4—Log Probability Chart showing typical particle size distribution for various types of coal firing

plates were used. The current trend is toward the use of plates, such as a dual plate of perforated or expanded metal, used either alone or in combination with pocket electrodes.

In a Cottrell, as in all forms of collectors, there are two problems: first, separating the solids from the gas and, secondly, separating the solids from the separator. This latter problem can be extremely difficult. For example, in a dry-type, fly-ash precipitator, ash is rapped or jarred off the collecting surfaces and falls by gravity into the hoppers. It may fall direct or through some protected channel but it must be kept in the hopper and not allowed to become re-entrained in the gases. When using pocket electrodes with rods for the high-tension system, the hopper can be covered with "steeples" so as to reduce hopper sneak-by to minimum value; see Fig. 3.

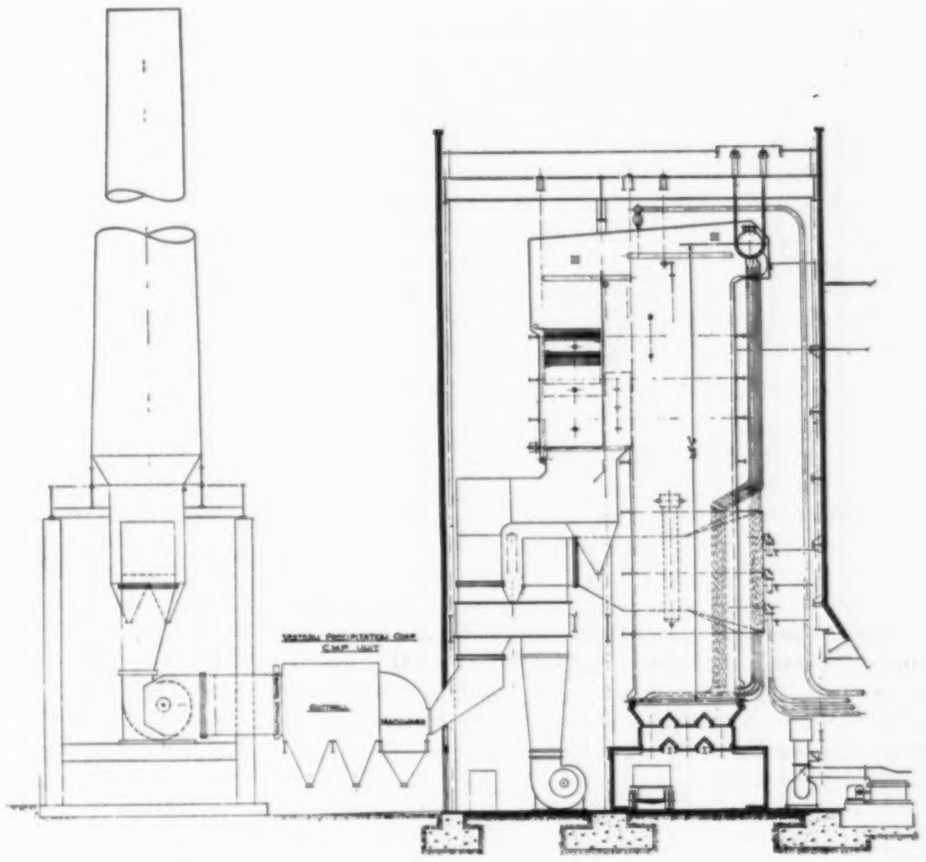


Fig. 5—Cross-section of CMP (Cottrell-Multiclone) Unit

Current Rectification

For producing unidirectional high-potential alternating current, three types of equipment are in use: namely, mechanical, electronic and static rectifiers. The mechanical rectifiers have been most commonly used throughout the power plant industry. This is a development of Dr. Cottrell and is a simple rotating switch driven by a synchronous motor. The electronic rectifier was first used in the mining industry some 25 years ago, but was not too successful because of tube failures. Since the development of more reliable tubes it became more or less standard for the large number of Cottrell precipitators installed during the war for the recovery of catalyst from regenerators. Here the carbon was burned from the catalyst in high-octane gasoline plants and the waste gas passed through a combination of mechanical separators followed by Cottrell equipment to recover the valuable material. Static rectifiers, such as copper oxide rectification, have been used but they are large and cumbersome. Selenium rectifiers are being used in certain types of precipitators.

Advantages of electrical precipitation are the low draft loss, of a few tenths of an inch water gage, and the fact that the efficiency can be adjusted to requirements. Cottrells are particularly effective on the fine particles that pass through mechanical collectors. The chief disadvantage is the fact that they are more costly and, like baffle chambers, bulky and space consuming. They also have three well-known weaknesses for collecting fly ash from pulverized-coal-fired boilers. The first is the puff of re-entrained dust that occurs during rapping, which is now being minimized through the use of closed damper rapping or continuous rapping; the second is that unburned carbon in the ash adversely affects the collection efficiency; and the third, that large particle material more easily erodes off the collecting electrode and if not recovered passes into the outlet gas stream. In some cases maintenance on induced-draft fans following precipitators has been quite high due to this latter weakness.

Physical Characteristics of Fly Ash

The log probability chart, Fig. 4, shows typical particle size distribution for various types of coal firing. It will be noted that pulverized coal firing, due to its very nature, gives a much finer fly ash, making it more difficult to collect. In general, the slope of the curve for pulverized coal, or other types of firing, will have the same general characteristics between various installations but, due to differences in coal preparation, furnace design and firing method, the position may be shifted one way or the other, thereby increasing or decreasing the amount of minus 10 micron material.

Another physical property of fly ash is its abrasiveness. This is governed largely by the amount of silica and coke particles present. For the most part, the apparent density of fly ash does not vary over a sufficiently wide range to be of too much importance.

Electrical Characteristics of Fly Ash

Fly ash was once regarded as more or less fairly uniform material in so far as its precipitability in the

electrostatic field in the Cottrell precipitator was concerned. It was known that ash containing high percentages of combustible was difficult to collect since the carbon particles tended to pass through the precipitator. More recently work on the conductivity or so-called apparent resistivity of fly ash has shown a wide variation; for example, strip-mined coal fly ash usually has a much higher resistivity or lower conductivity than fly ash from deep-mined coal, and experience indicates it to be more difficult to separate from the gas stream.

The following table indicates the typical grain loading from various types of boiler firing:

	Gr/Cu Ft of Gas
Pulverized coal	1 to 12
Chain grate stoker	2 to 5
Underfeed stoker	0.5 to 1.5
Spreader stoker	2 to 12

Selection of Equipment

The selection of suitable fly-ash equipment is determined by various factors, such as the method of firing, type of coal and the physical and electrical characteristics of the resultant ash leaving the boiler, as well as the efficiency required.

For stoker-fired installations the current trend is to use baffle or centrifugal-type separators. Centrifugal separators will provide efficiencies on the order of 85 to 98 per cent which will satisfy most requirements.

For pulverized-coal-fired boilers, the trend in the last few years has been toward efficiencies of the order of 95 per cent, but more recently 97 to 98 per cent continuous efficiency has been specified. This has led to the use of a combination of mechanical and electrical separators, which has certain advantages.

A combination of mechanical and electrical separators was first used in the mining industry some years ago where the selective classification of the coarse material permitted it to be returned directly to the roaster for further treatment while the fines, ofttimes carrying compounds such as arsenic, were carried over and recovered in a Cottrell for separate treatment. Installations in the cement industry followed, where the mechanical separator catch was returned directly to the cement kiln while the Cottrell catch contained the fine and high alkali fume material which was disposed of otherwise.

In the fluid-catalyst petroleum cracking plants mentioned previously, mechanical collectors recovered and returned the major portion of the material direct to the catalyst bed in the regenerator and the fines, consisting

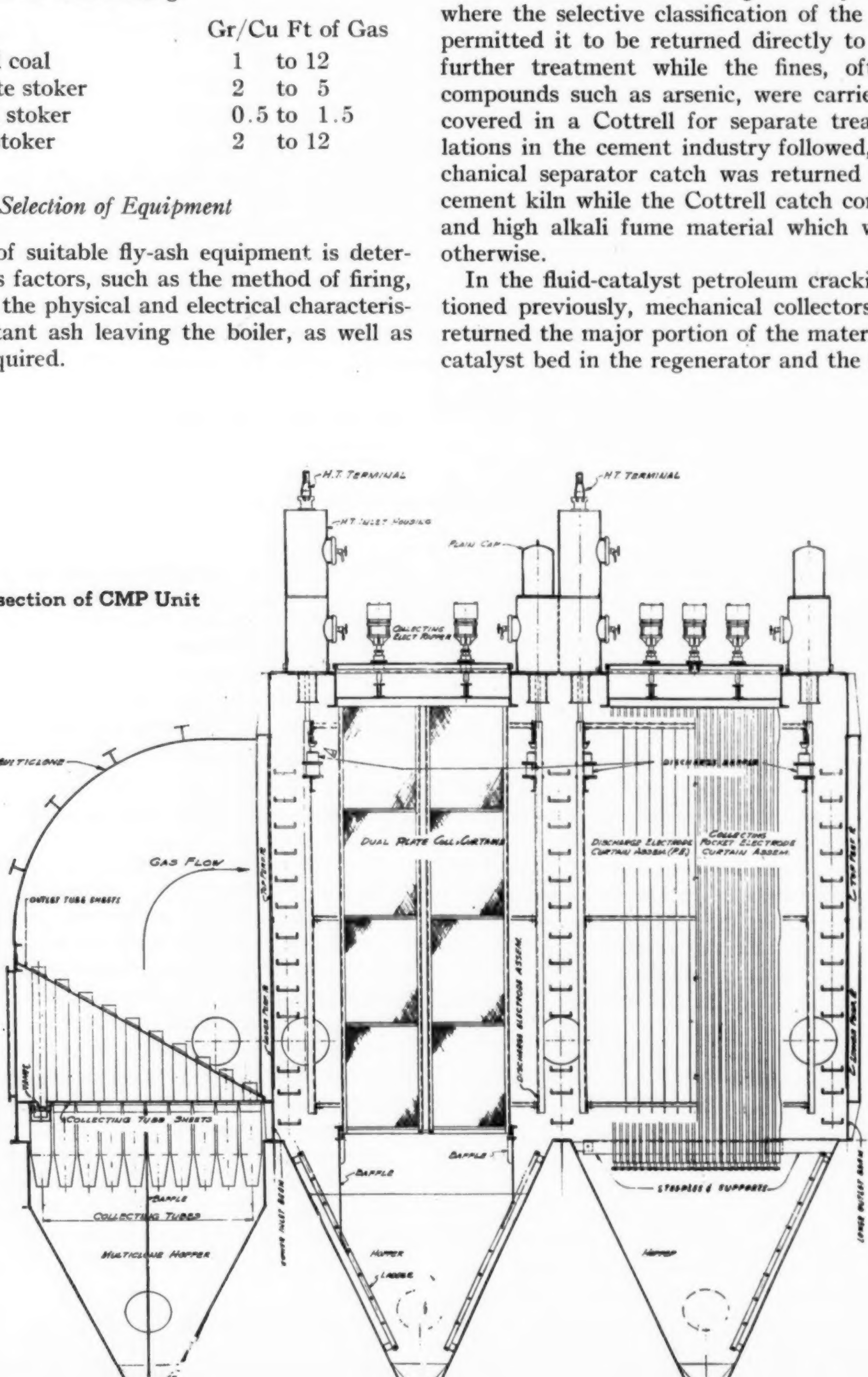


Fig. 6—Cross-section of CMP Unit

mostly of minus 10 micron material, were recovered in the precipitators from which they could either be recirculated or removed from the process. The efficiency of this combination was in most cases over 99.9 per cent.

In the past there has been a tendency on the part of manufacturers of electrical precipitators to install equipment for around 90 per cent efficiency or just above that obtainable with mechanical collectors. On the other hand, there has been a tendency on the part of mechanical collector manufacturers to decrease clearances in the mechanical separators to bring about efficiencies approaching 90 per cent, thus losing some practical advantages. The use of the combination of mechanical primary plus electrical secondary for the recovery of solids from gases is much the same as the use of the most practical and economic heat-exchanger surface for the recovery of heat from gases in their passage through the overall steam-generator heat-recovery unit. A wide variety of heat-exchanger surfaces is available to the designer of the steam generator and he uses it judiciously. The same policy is now receiving favor among designers in selection of fly-ash collectors where the separator is chosen to do that part of the work for which it is especially suited; see Figs. 5 and 6.

Placement of Mechanical and Electrical Collectors

Mechanical collectors have almost always been used ahead of electrical precipitators, except in the carbon black industry where the very fine particles will agglomerate and here the gases pass through the precipitator at sufficient velocity so that the material agglomerated on contact surfaces is eroded off and caught in large diameter cyclones. Pulverized-coal fly ash for the most part shows only a slight tendency toward agglomeration and does not exhibit the properties of carbon black; nevertheless, the common question is where should the mechanical collector be for best fly ash recovery—before or following the Cottrell?

If the mechanical collector follows the Cottrell, its main use will be to catch the coarser ash and unburned carbon particles that tend to pass through the Cottrell. Another advantage would be to eliminate to some extent the heavy losses in puffs from the precipitator during rapping. A third reason would be to recover carbon particles during the soot-blowing period when the grain loading may go up to many times normal and load the precipitator with material that it does not retain very well.

On the other hand, a mechanical collector preceding a precipitator has numerous definite advantages. Having a classifier action, it passes on to the Cottrell only the smaller micron sizes; the majority, 10 microns and under. As stated earlier, the Cottrell is more ideally adapted to collection of the finer fractions. The coarser fraction thus recovered in the mechanical collector keeps a portion of the unburned carbon from getting into the precipitator. In one installation the combustible entering the multiclone was from 21 to 22 per cent and at the outlet from the precipitator 14 per cent. For the same installation, burning a combination of coal and oil with an inlet to the multiclone of 41 per cent combustible, the precipitator outlet indicated 23 per cent. In a test on the multiclone only

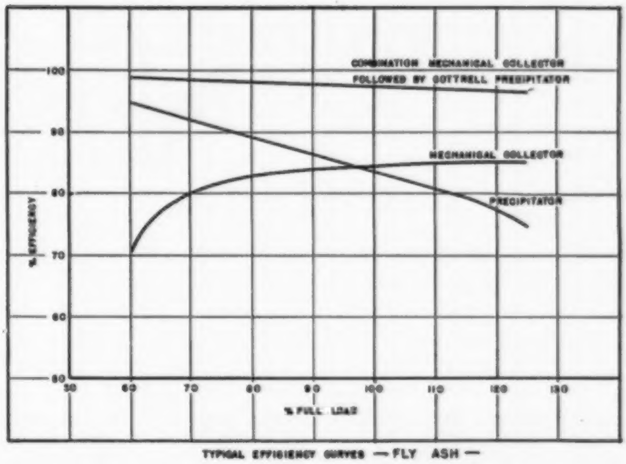


Fig. 7—Efficiency Chart showing typical efficiency of a mechanical collector, a precipitator and a combination of the two for various loads

while burning coal and oil, the combustible was 38 per cent at the inlet and 20 per cent at the outlet. This indicates that the mechanical collector removes the major portion of the unburned carbon.

As mentioned previously, during soot-blowing periods when grain loadings may be as much as ten times normal and high in carbon, the mechanical collector efficiency percentage-wise will ordinarily increase to some extent and will prevent the bulk of this material from reaching the Cottrell. This characteristic is also advantageous when a boiler is being started or being brought up to load and there is a tendency toward somewhat poor combustion and large gas volumes which place an overload on the fly-ash collection equipment.

Electrical precipitators are more ideally suited to the handling of light dust concentrations. When they are suddenly confronted with heavy dust concentration or variable dust loads at the inlet, it is necessary to compensate for this. A precipitator has a tendency to operate more smoothly with a light grain loading.

If, for any reason, the precipitator becomes de-energized, the mechanical collector will still be removing a major portion of the fly ash. During normal operation with only 12 to 20 per cent of the fly ash passing to the precipitator, it is not necessary to rap it as often.

A Cottrell has never been installed ahead of an air heater, in so far as the writer knows, although mechanical collectors have been so used. In one such case a Cottrell was installed on the low temperature side of the air heater to recover fines lost by the mechanical collector. In other instances, mechanical collectors are installed initially and space provided so that at some future time an electrical precipitator can be added if changed conditions require higher recovery.

A mechanical collector preceding a Cottrell precipitator makes a complementary arrangement in that, as the boiler load increases, the fly-ash load also increases and likewise the draft loss across the mechanical collector increases. Fig. 7 shows typical efficiency of a mechanical collector, a precipitator and a combination of the two for various loads. It will be noted that, although the precipitator efficiency drops rapidly with increase in load, the rising mechanical collector efficiency curve compensates sufficiently so that the overall percentage efficiency is approximately constant.

Midwest Power Conference

WITH a registration of around 1500 and an attendance estimated at more than 2000, the Twelfth Annual Midwest Power Conference, at the Sherman Hotel, Chicago, on April 5–7, comprised an extensive program, including groups of papers on feedwater conditioning, smoke abatement, power station design, system operation, steam generation, diesel engines and the gas turbine. In all, there were over fifty papers besides numerous addresses and luncheon talks. As in the past, the Conference was sponsored by the Illinois Institute of Technology with the local sections of various national engineering societies and a number of midwestern colleges and universities cooperating. Following are some of the highlights of the Conference and abstracts of certain papers believed to be of particular interest to COMBUSTION readers.

At the opening session Wednesday morning, **Edward J. Doyle,** president of the Commonwealth Edison Company, reviewed the program of that company and its affiliates in the Chicago region. The December peak exceeded $2^1/_2$ million kilowatts, backed by very little reserve, but the 1947–1952 expansion program of 774,000 kw is now about half completed and places the company in a stronger position to meet increasing demands. At the new Ridgeland Generating Station the first of two 150,000-kw units will go into service late this year, and the second in 1951. This station is planned for an ultimate capacity of 600,000 kw, with steam conditions of 1800 psi, 1050 F.

Following a response by Prof. **D. D. Ewing** of Purdue University, **Walter T. Fisher** of the Illinois Commerce Commission told of the various regulatory problems involved in the work of the Commission and pointed out the shortcomings of centralized federal controls from Washington.

Power in New England

The next speaker was **John I. Ahern,** representing the Massachusetts Electric and Gas Association, who discussed the political background underlying current efforts of public ownership proponents to create a federal power authority for New England. Much of this agitation he traced to the Department of the Interior at Washington, abetted by certain socialistically minded individuals and local politicians in New England. Exclusive of Maine, whose laws prohibit the export of electricity beyond state lines, there is very little remaining undeveloped water power in New England, such as would be economically feasible to develop. Its topography and distribution of population preclude flooding of vast areas such as has been possible in certain other sections of the country. Furthermore, largely through expansion of steam capacity, the New England power companies have been able to keep abreast of all energy demands. The speaker then reviewed the fiasco of the Passamoquoddy tidal project which cost the taxpayers over 7 million dollars without accomplishing anything.

Coal's Place in The Sun

This was the title of a paper by **B. A. Landry** of Battelle Memorial Institute, which attempted to answer three questions, namely: (1) What is coal's importance in relation to oil and gas? (2) What are the competitive aspects, in the immediate future, of these three segments of the fossil fuel industry? (3) What general policies on the part of the coal industry would best appear to be indicated to improve coal's position?

Excluding those sections of the country, such as the Gulf Coast, the Southwest and the Pacific Coast, which are devoid of high-grade bituminous coal but have abundant oil and gas, the author concentrated on the regions in which coal, oil and gas are competitive. Here there was a marked increase in consumption of fuel oil and gas from 1946 through 1949 and a decrease in coal of about 51 million tons. Despite this, coal in 1949 was still the most important source of fuel energy.

The principal factors in this situation were stated to be the continued conversion of steam motive power to diesel operation, the expansion of natural-gas pipe lines, and the tendency for increased yields of fuel oils from domestic petroleum in view of the growing availability of natural gasoline and increased petroleum imports.

Despite the increase in refinery flexibility, the yield of gasoline, over the past few years, has remained rather constant at about 40 per cent, owing to ready sale of distillate fuel. Rising prices of coal further favor a higher yield in fuel oils.

Mr. Landry summarized this situation by predicting that in the next five years coal stands to lose 20 million tons by dieselization, 80 million tons to natural gas and 20 million tons from additional sales of fuel oils.

To combat the decline and enhance coal's position he suggested that full advantage be taken of recent research in the handling and burning of coal without smoke, and disposal of ashes, to approach the convenience of fluid fuels; and that the continuing increase in electric utility capacity offers the most promising market for solid fuel. Therefore, since energy in the form of electricity represents the most versatile form to which the chemical energy of fuels can be converted, it is to the coal industry's advantage to promote the use of electricity in all its varied applications.

Fuels from Oil Shale

Citing that the idea of producing liquid fuels from oil shale dates back to 1681 when such a patent was issued in England concerning "oil from a kind of stone," and that a French shale-oil industry was in existence in 1838, **Boyd Guthrie** and **R. J. Cameron,** of the U. S. Bureau of Mines, gave the following explanation of the term:

"Oil shale," they said, " is a sedimentary rock that contains a solid, organic material known as kerogen. Although the rock contains virtually no oil as such, when

it is heated to around 800 F the kerogen is converted to shale oil, a combustible gas and a carbonaceous residue. The residue remaining after retorting and the gases produced can be burned to supply more heat than is required to cause decomposition of the kerogen. Shale oil can be refined to produce fuels similar to those obtained from petroleum."

Oil shale deposits occur abundantly in Europe, Australia, Manchuria and North America. In the United States, with principal deposits in Colorado, Utah and Wyoming, they are capable of yielding shale oil in quantities that would dwarf our present known reserves of petroleum.

As a part of the Government's synthetic liquid fuels program, demonstration-scale studies on mining and processing oil shale are being made by the Bureau of Mines at a plant near Rifle, Colorado. A small experimental refinery producing finished fuels from shale oil is also in operation. This work is producing results that eventually may be the basis for an oil-shale industry in this country.

Crude shale oils from Colorado shale have a high pour point and high viscosity. Compared with a typical mid-continent crude oil they are high in nitrogen and sulfur.

Refining can be accomplished either by the conventional thermal cracking techniques to yield gasoline, distillates, residual fuels and coke or by employing the hydrogenation process.

As to cost, the authors expressed the opinion, based on present information, that it is more difficult and expensive than to refine a good grade of petroleum, but that the cost may not greatly exceed that of refining a high-sulfur crude of comparable A.P.I. gravity.

Power Station Design Factors

"Basic Factors of Steam Power Plant Design" was the topic of a paper by **B. C. Mallory** of Stone & Webster Engineering Corporation. Thorough studies of details are required for successful design, which should be based on an investigation of the economics of available equipment and consideration of probable operating conditions. Some of the early decisions that must be made relate to initial steam conditions and the desirability of reheat. To make them, the size of the unit, expected load factor throughout its useful life and the expected fuel cost must be known.

Mr. Mallory next discussed the merits of arranging power equipment to approach what he characterized as a "skyscraper" or a "ranch-house" design. In the former, station components predominate on a vertical plane having relatively small cross-sectional area. For the latter as much of the equipment as possible is laid out in the same horizontal plane.

With the reliability of steam generating units approaching that of the turbine-generator, steam interconnections between units may be omitted. This is a distinct advantage in a plant employing the regenerative-cycle, for it avoids the necessity of balancing condensate and extraction flows between units. There is also the question of the seldom-used interconnections which may cause equipment outages due to improper operations.

The development of dependable automatic controls has, to a large extent, made possible the evolution of power stations to their present form. Grouping of instruments and control apparatus in a central location requires a minimum number of station operators. Some of the factors which should be taken into consideration in designing centralized control include:

1. The number of operators required for starting, stopping or operating under adverse conditions. This will depend upon the type and arrangement of station equipment and the fuel burned.
2. The quality of operators available, with consideration of the effect of clean, well-lighted and ventilated working space.
3. The number and size of units installed or projected.
4. Whether the station is designed for common header or unit operation.

The obvious fact that additional investment in centralized control cannot be justified by labor savings, if the number of required station personnel cannot be reduced, should be kept in mind.

For single boiler-turbine-generator units the control function may be considered somewhat different from common header operation. In the former each unit produces kilowatt-hours; the boiler may be considered an auxiliary of the turbine-generator; and it appears logical to group the instruments and controls for each turbine, boiler and their auxiliaries in a convenient location which is centralized with respect to the unit. On the other hand, when a common header system is used, the product of the boiler plant is steam, which may be thought of as the raw material of the turbine-generator plant. Methods of supervisory control for this arrangement, it should be apparent, might be quite different from the unit system, for the boiler controls might be centralized in one location and the turbine controls in another.

Steam Plant Design Trends

Pointing out that a review of current trends in steam power plant design can act as a stimulant for progressive thinking and new ideas, **Paul E. Gourdon** of Ebasco Services, Inc., presented a paper entitled "Trends in Modern Steam Plant Design." In this he emphasized that the utility industry has made a generally successful effort to maintain service of high quality and reliability in the face of mounting central station investment costs and increased fuel, operating and maintenance expenses.

Some of the new ideas which enable management to effect economies under certain conditions include the single boiler-turbine-generator unit, the outdoor plant, centralized control of a higher degree than previously practiced, cooling-tower installation where condensing water supply is inadequate, use of lighter-capacity main station crane, condenser deaeration, and the increasing employment of the model as a design tool. Mr. Gourdon analyzed each of these developments from an objective point of view and supplied specific instances of their economic application in central station practice.[1]

[1] A more detailed abstract of this important paper will appear at a later date.

Reheat Turbine-Generator Units

In discussing "Developments in High-Temperature and Reheat Turbine-Generator Units," **J. R. Carlson** of Westinghouse Electric Corporation emphasized the importance of economic gains obtainable by using higher steam pressures and temperatures in thermal power plants.

Ordinary low-carbon steel castings and forgings limit steam temperatures to a range of 750–825 F, but the development of chrome-molybdenum steels in the early 1930's made possible advances to 950 F. At the same time longer low-pressure end blades were designed for 3600-rpm condensing turbines, some of these blades being 20 or 23 in. in length and operating at top speeds in excess of 850 mph. To achieve operation at 1000 F, 1650 psig, materials having a chrome content of $2^1/_4$ per cent were employed, while to go to 1050 F high-pressure turbine elements were made of an austenitic 18-per cent chrome, 8-per cent nickel alloy.

Mr. Carlson expressed the opinion that increases in steam temperature above 1050 F should be coupled with the use of reheat. While raising operating steam temperature from 1000 to 1050 F results in a 1.3 per cent increase in operating economy, a $4^1/_2$ per cent improvement in station performance may be obtained by having 1000 F initial temperature with one stage of reheat to the same level. He added, "Expressed in another manner, when steam is reheated to its initial temperature, the reduction in heat rate is equivalent to that obtained by increasing the initial steam temperature by 150 to 200 F with the non-reheat cycle." In effect, use of reheat means that the same heat rates as those beyond the range of present-day central station experience can be obtained with temperatures now considered moderate and well tested.

In going from 1000 to 1050 F incremental turbine cost is twice that of raising steam temperatures from 950 to 1000 F, the increase being attributable to the use of nearly eight times as much chromium in the austenitic steels required for the higher temperature.

The first Westinghouse turbine designed for a reheat temperature of 1000 F was placed in service in 1949 at the Edgar Station of the Boston Edison Company and to date operation has not only been satisfactory but also simpler than was originally anticipated. At present reheat turbines are being designed and manufactured with ratings beginning at 60,000 kw (generally for steam conditions of 1450 psig, 1000–1000 F) and extending to 125,000 kw or more.

Mr. Carlson drew the following conclusions:

1. Even though the majority of turbines have been purchased for steam conditions of 1250 psig, 950 F or lower, it is believed that there will be a marked trend in steam conditions to 1450 psig, 1000 F and higher.
2. The newer turbines designed for operation at 1000 F and 1050 F with their corresponding optimum pressures will prove to be as reliable and easy to operate as turbines designed for lower steam conditions.
3. With large capacity turbines for higher steam conditions, reheat should be considered a necessary adjunct to achieve the most economic results.
4. The single-shaft, 3600-rpm, turbine-generator unit will eventually supersede the 1800-rpm unit for all rating through 150,000 kw.

Improvements in Central Stations

Emphasizing that improvements in the cost of producing power start with consideration of the cost and availability of fuel, **G. A. Gaffert,** of Sargent & Lundy, reviewed briefly various steps that have been taken to produce improved efficiencies and higher availability. But with mounting fuel prices, a reappraisal of the cost of increasing overall boiler efficiency, as compared with fuel savings, indicates the desirability of designing for efficiencies of 87 to 90 per cent. The latter involves an exit gas temperature of around 275 F and, in turn, requires a large air heater with provision for recirculation and use of corrosion-resistant alloys where midwestern coals are concerned.

One late development is pressurizing the furnaces, accompanied by elimination of the induced-draft fan. In this case counter-blast furnace doors must be used, properly inter-locked to allow furnace observation; and the furnace must be adequately braced. According to the author, a 25-per cent reduction in total fan power and an increase of $^1/_2$ of 1 per cent in boiler efficiency is indicated, and there is not much difference in first cost between a conventional boiler and a pressurized one, the parts affected being the casing and the fans. It is difficult to justify high-pressure, high-temperature cycles and high heat recovery in the Southwest where fuel is relatively cheap. Steam generating units in this area employ air heaters only for moderate recovery.

By the application of variable-speed couplings the part-load input power has been materially reduced. Also, in the case of very high-temperature plants, of 1000–1050 F, it is advisable to reduce or eliminate the use of auxiliary high-temperature steam.

Station heating of large stations, especially those of unit plant design, may well be done with auxiliary gas- or oil-fired units, separate from the power cycle.

While we have come to accept 1500 psi, 1000 F as a modern standard for which adequate metallurgy is available, a few stations have been designed for 1050 F, and considerable attention is being given to the reheat cycle involving 1500 psi, 1000 F and reheat to 1000 F. This has come about because of higher boiler availability for the unit plant, a considerable simplification of the reheat cycle protective devices and realization of a gain in economy comparable with an advance in steam temperature to 1150 F for the straight regenerative cycle. It will also be found that the reheat cycle pays a 20 to 25 per cent return on the added investment over the straight cycle.

Power System Reserve

Howard P. Seelye of The Detroit Edison Company, in answering the question posed by his subject, "What Reserves Should Be Provided in a Modern Power System?," declared that the amount of reserve margin may be quite different for different systems and even for different times on the same systems. It is not a simple matter to decide upon reserve capacity, which may be affected by such factors as system size, provisions for interconnection, equipment condition, service quality desired, company policy, load character, and the degree of acceptable risk. There is no one best answer to the reserve problem and individual judgment is a large part of any decision. For these reasons Mr.

Seelye chose to discuss only the conditions influencing and methods of reaching a choice of reserves.

Reserve may serve the following functions:

1. Allow equipment to be removed for maintenance without impairing service.
2. Provide for carrying a load greater than expected.
3. Enable the carrying of a load in emergencies when part of the equipment has failed.

While the amount of reserve necessary for these functions may, for convenience, be considered separately, the total provision serves all three purposes and need not be the sum of the three taken individually, since their combined maximum requirements are not likely to be simultaneous. If reserve requirements are understood and formulated clearly, they may be an aid to decided future additions of system capability.

In considering reserve for maintenance, important factors are type of equipment, character of load, amount and kind of work to be done, and local costs. Reserve for equipment parts having frequent outage may reduce that needed for others, as in the case of spare or duplicate auxiliary units. Careful attention to costs, scheduling, and keeping of equipment in good condition all have a bearing on outage records and reserve need for emergencies.

Reserve for unforeseen load is dependent upon the uncertain art of load forecasting. Tentative predictions of continued trends must take into account the upsetting possibilities of changing business conditions, new electric devices, stimulated sales programs and new loads coming into the territory. Two practical considerations which can temper over-optimistic load provisions are the fact that very large new loads take some time to develop (allowing for at least temporary provision to meet them) and the feasibility of encroaching for a short period upon reasonably ample reserves carried for other purposes.

Emergency reserve must be carried to allow for failure of any piece of operating equipment. By their very nature the time and extent of these failures cannot be foreseen, but they can be anticipated by taking into account the probability of failures and their effect upon system operation.

In summarizing the paper, Mr. Seelye stated that adequate reserve capability to insure continuity of service under reasonably expected emergency conditions must be a part of good service for customers of a power system. Such reserve represents an essential and legitimate financial investment.

Dual-Circulation Boiler

In a paper entitled "The Dual-Circulation Boiler, Its Design and Operation," **R. H. Lorenzini** of Foster-Wheeler Corporation stated that this type of boiler grew out of the necessity of utilizing feedwaters of high silica or solids content to generate nearly pure steam in high makeup, high-pressure units.

In the dual-circulation boiler the principle of stage evaporation is utilized, there being two separate heat-absorbing sections, each with its independent circulating system. This is, in effect, the same as two boilers in a single setting with the blowdown from one section constituting the feed for the other. Concentration is maintained at a lower value in the primary section which can safely be subjected to higher absorption heat rates than are necessary in the secondary or convection section.

The steam drum internals are the heart of the dual-circulation boiler, and they must be designed so that water from the secondary section is withdrawn from the primary section at a point where the maximum concentration exists. Either single or multi-drum boilers may be built to this design, the choice being dependent upon anticipated feedwater conditions, design pressure and allowable steam release rates.

Simplicity of operation is said to characterize the dual-circulation boiler, which requires much the same instrumentation and controls as a conventional boiler. Feedwater conditioning control is simplified because variation in blowdown or rating have little effect on primary-section concentrations and because of the rapidity with which equilibrium boiler-water conditions are attained.

Feedwater Heating and Deaeration

A. E. Kittredge, of Cochrane Corporation, discussed the problem of deciding whether to employ a completely closed system, a deaerating condenser, a substantially closed system with a direct-contact deaerating feedwater heater installed in one of the intermediate stages or a completely direct-contact system. These questions he reviewed from the standpoints of first cost, reliability and maintenance, operating efficiency and corrosion protection.

While the closed system is simpler, it must be remembered that when deaeration is accomplished in the main condenser, the maintenance problem must comprehend means for positively preventing in-leakage of air, as this may prove a serious matter. However, several well-known utility companies were cited as depending upon the condenser as the only means of attaining deaeration.

In the small central station the direct-contact deaerating heater was shown to possess advantages.

The author expressed the opinion that in the sense that a deaerating condenser strives to accomplish deaeration, it is a desirable device, but that a deaerating feedwater heater provides positive insurance and security against oxygen in the feedwater. He then described various types of deaerating heaters, certain operating problems, and performance.

Demineralization vs. Evaporators

In a paper entitled "Demineralization as Compared with Evaporation of Makeup for Surface Condensing Power Plants," **J. D. Yoder** of The Permutit Company reviewed the practice of inserting a makeup evaporator between two successive extraction points of the turbine. He pointed out that, while this arrangement recovered all the Btu's of the evaporating process, except the heat lost in blowing down the evaporator, there nevertheless was a substantial energy loss through degrading the heat in the evaporator coils to a lower pressure. While the energy loss with an evaporator can be reduced perhaps 50 per cent, although not eliminated, by employing an evaporator-condenser and drain coolers, this adds to the complication and cost of evaporating equipment and is not ordinarily used in the average size plant.

However, recent improvements in feedwater treatment make it possible to produce a demineralized water with substantially the same constituency as condensate from a commercial evaporator. This may be used for makeup without degrading heat, so that energy loss on this account may be avoided.

Mr. Yoder then described equipment for demineralizing raw water. In this the makeup water first passes through a cation remover, then through a degasifier for CO_2 removal, and finally through a combined anion and silica-absorbing unit. The demineralized water, he pointed out, can be delivered directly to the surface condenser in such a manner that most of the oxygen is removed and the effluent from the hotwell should not have more than about 0.03 cu cm of oxygen per liter. Such water is suitable for passing through the No. 1 low-pressure heater, from which it enters the deaerator for complete oxygen removal.

Typical heat balances for both arrangements were shown, involving different percentages of makeup, as well as tables comparing boiler water conditions when demineralizing with those when using evaporated makeup.

Deposits in Closed Feedwater Heaters

Warren S. Kane, of the Iowa Public Service Company, told of experience with deposits in heaters and economizers at the Kirk Station in Sioux City. This is a 700-psi plant containing three boilers and a turbine-generator, the major part of the exhaust from which goes to a non-return heating system. Feedwater supply is taken from wells and, as raw water, has an average hardness of 400 ppm as $CaCO_3$. Makeup is about 80 per cent, and the high-pressure heaters are designed for an outlet temperature of 356 F. All makeup water and condensate are mechanically and chemically deaerated before admission to the high pressure feedwater system.

Before sodium aluminate was used as a supplemental treatment in the softeners, the hardness of the treated water averaged 12 ppm as $CaCO_3$. Use of sodium aluminate reduced this hardness to 7 ppm.

With increase in station load, heater fouling became serious and it became necessary to employ acid washing as often as 15 times in one year in order to maintain the desired feedwater temperature.

However, in 1946, a processed lignin derivative was applied at a dosage of 4 to 5 ppm, based on total boiler feedwater and immediate improvement in the maintenance of feedwater temperature at the heater discharge was observed. In other words, before the lignin was employed it was usually not possible to operate the heater for more than 600 hr without a temperature drop of 25 to 30 deg F, whereas the treatment permitted operation for 7200 hr before acid cleaning.

Magnetic Iron Oxide Deposits

A Symposium on this subject, under the chairmanship of **J. A. Holmes** of National Aluminate Corporation, was sponsored by the Joint Committee on Boiler Feedwater Studies and comprised five papers, together with extensive discussion.

The first of these papers, dealt with the results of "Experimental Studies of Iron Oxide Deposits in Boilers" which were reported by **Clarence Jacklin** and **Harris Thompson,** both of National Aluminate Corporation. These were made on a laboratory boiler to determine whether rapid attack and failures result from (*a*) insulating action of the iron oxide deposits, from (*b*) firing conditions which give intermittent or continuous water-starved areas with resulting concentration of solids at the heat-transfer surface, or (*c*) whether a combination of both iron oxide deposits and high heat-transfer rates are necessary to produce attack.

During tests a pressure of 2400 psi, plus or minus 100 psi, was maintained in the removable $1^1/_2$-in. heating tube and, by means of electronic induction heating, a heat-transfer rate of 200,000 Btu per sq ft per hr was uniformly maintained. All the feedwater, which was free of calcium and magnesium, was mechanically deaerated and treated with sodium sulfite to maintain a sulfite residual of 20–25 ppm in the boiler water. Sodium salts were employed.

In the first test, which lasted 100 hr, no iron was added and a very thin uniform gray-black layer of small magnetic iron-oxide crystals appeared on the heated area of the tube, but without build-up of deposits.

For the second test 5 ppm of iron was added to the feedwater and tube failure occurred after 28 hr due to overheating and collapse, the overheated area being covered with a dense, hard, black deposit of magnetic iron oxide.

Test No. 3 was also made with 5 ppm of iron added to the feedwater, but a tapered induction coil, instead of a uniform coil, was employed. Failure occurred in 50 hr with the distorted area resembling that in the previous test, but there was a heavier deposit of porous magnetic iron oxide on the lower heat input area near the point of failure.

The fourth test, similar to No. 3, except for high alkalinity in the boiler water, did not produce failure in 50 hr, but showed severe pitting under a heavy layer of iron oxide.

From these tests it was concluded that in boilers having localized high heat transfer and probable water-starved areas, high boiler-water alkalinity is undesirable; also that iron in the boiler water greatly speeds the rate of attack on the tube metal. Prevention of corrosion in pre-boiler systems, as well as in the boiler itself, is most important, as such corrosion may be the source of iron oxide which is transferred by the circulation to a high-heat location where it may cause failure.

"Steel, Heat and Water: Localized Formation of Magnetic Iron Oxide in Power Boilers," by **H. M. Rivers** and **W. M. Sonnett,** both of Hall Laboratories, was the title of the second paper. In this the authors pointed out that iron in contact with boiler water tends to corrode spontaneously. Water is decomposed in the process, liberating hydrogen gas and producing magnetic iron oxide (Fe_3O_4) as the main corrosion product. Being extremely insoluble, this iron oxide normally precipitates directly on the metal.

A thin film of magnetic iron oxide normally protects boiler metal from attack by water; and corrosion will

occur if, and only if, the protective film is broken down. Erosion, sudden temperature changes, and other physical or mechanical factors may damage the film and permit corrosion.

Chemical breakdown of the film may be caused by oxygen dissolved in the boiler water, by galvanic forces set up by porous or lightly adherent deposits, by strong concentration of boiler water caustic, or by exposure to superheated steam at very high temperature. Oxygen dissolved in boiler water will cause corrosion in the form of pits not restricted to heat-transfer surfaces, these pits being characteristically covered by or filled with iron oxide. Good deaeration and oxygen-scavenging chemicals generally suffice to control this type of attack.

However, steel sometimes continues to corrode under old tubercles of oxide when no measurable amount of dissolved oxygen is present. In such cases it is supposed that the corrosion products behave as a water-permeable membrane, setting up differences in concentration which allow the metal underneath to become relatively anodic and thereby corrode, while water is decomposed to supply oxygen for the production of more iron oxide.

Any condition that aids these corrosive influences, such as localized overheating, retarded circulation, steam blanketing, etc., will contribute to attack.

Magnetic iron oxide, produced in proportion to the loss of metal, may remain near the corroded area, or deposit elsewhere in the boiler. The hydrogen released by reaction between the water and steel will either pass off with the steam or be absorbed by the metal, sometimes causing brittleness due to intergranular damage. Moreover, metal that has failed through overheating, as indicated by changes in microstructure, always shows signs of corrosion, unless a layer of scale has sealed it from direct contact with water or steam.

Experience with iron oxide scale and copper deposits in a 420-psi boiler at the Hoot Lake Station of the Otter Tail Power Company were related in a paper by **John H. Moore,** general plant superintendent of that company.

This plant, which went into service in August 1948, contains a two-drum, two-pass spreader-stoker-fired boiler with an economizer, serving a 7500-kw condensing turbine-generator. The condensate and feedwater are in a closed system originally designed with no deaeration other than that obtained in the main condenser. Undeaerated raw lake water for the evaporator makeup is treated with sodium aluminate, plus a stable lignin derivative, with antifilm and caustic. At the feed pump suction there is added a stable lignin derivative; and an orthophosphate is introduced into the lower drum.

During the late fall of 1948 traces of magnetic oxide of iron showed up in the boiler blowdown and the amount continued to increase.

Early in May two leaks and a blister developed in the furnace wall tubes and the unit was shut down for inspection. This revealed deposits at the lower ends of all side-wall tubes, extending some distance upward, as well as several blisters. The boiler was relatively clean except for a uniform coating of a reddish brown powdery deposit and tiny nodules of black iron oxide under this coating in many places. There were no indications of pitting. The iron oxide deposits were heavier on the fire side of the tubes and showed the presence of copper crystals, under a microscope.

Inspection of economizer tubes showed a uniform coating of a reddish brown powdery deposit lighter than that in the boiler but no nodules of black magnetic oxide of iron and no pitting.

When the unit was taken out of service for scheduled overhaul in June, it was acid-washed and rinsed with a caustic solution and raw water and a number of system changes made.

The theory advanced to explain the presence of the magnetic iron oxide deposit was that the basic trouble lay in the pre-boiler system, particularly the surge tanks which were heavily coated with red iron oxide, as was the boiler feed system. Furthermore, without deaeration other than the main condenser, gases passing over with the evaporator vapors reached the low-pressure heater shell; and with CO_2, ammonia, and oxygen present, some attack upon the copper-bearing metal of No. 1 stage heater and the drain heater could be expected. In fact, inspection of the shell side of this heater showed copper corrosion to have taken place.

"Causes and Prevention of Iron Oxide in Boilers" was the title of a paper by **S. T. Powell, L. G. von Lossberg** and **J. K. Rummel.** The authors pointed out that accumulation of iron oxide and other objectionable metallic oxides occur in boilers as a result of the aggressive attack on the metal in the steam-water cycle. Combinations of two or more physical and chemical actions induce this corrosion. Dissolved gases such as carbon dioxide, resulting from the decomposition of bicarbonates and carbonates in the feedwater and sulphur dioxide, generated by the decomposition of sodium sulphite in the concentrated boiler water, acidify the condensate returns and make them aggressive to the metal. Ammonia, or compounds which break down to form ammonia, can cause the condensate to be aggressive to copper alloys.

Damage to the protective, dense, adherent magnetic iron oxide film on the metal surfaces of the boiler results in aggressive corrosion. Caustic in the boiler water can concentrate under some conditions to damage this film. Overheating of the metal or alternate heating and quenching result in internal corrosion. Improper cleaning of the boilers, as well as other equipment in the regenerative cycle, has resulted in heavy accumulations of heavy oxides and damage to the boiler surfaces.

Prevention of black iron oxide deposits following chemical cleaning was discussed in the final paper of the symposium.

The usual procedure for acid washing of boilers is to fill the unit with a weak hydrochloric acid solution containing an acid inhibitor, and if necessary for removal of the deposits, a surface active agent and a fluoride intensifier. This solution is allowed to remain until the scale deposit is removed, following which the acid is drained, the boiler is given two water rinses and then a weak alkaline after-boil, usually a one-per cent soda-ash solution. The purpose of the after-boil is to insure neutralization of the acid, to act as a detergent for re-

moving any loosely held scale and to help passivate the metal surface. A film of iron oxide is formed on the metal surface during the three draining steps. While the presence of a protective film is necessary following the acid washing, under certain conditions this film is somewhat heavy and spotted.

The results of experimental work to control this film were reported by **P. H. Cardwell** of Dowell Inc. They indicated, as the most desirable method, that the formation of iron-oxide film be controlled by displacing the acid by means of water or by displacing the acid and water rinses by means of nitrogen. Such displacement techniques have been found to reduce the iron-oxide film as much as 50 to 90 per cent.

Water Treatment for Utility Plants

At the third session on feedwater treatment a paper by **F. G. Straub** of the University of Illinois cited results from experience in a number of the larger electric utility plants in preventing boiler metal failure and thus assuring high availability.

Development in the use of phosphates, hydroxide and oxygen scavengers to prevent scale formation and corrosion in boilers, he pointed out, has led to certain chemical controls, and methods of analyses have been developed for accurate and rapid determination of the various chemicals either found in or added to the cycle. Unfortunately, this has sometimes led to the erroneous opinion that if the chemicals added to prevent scale and corrosion are present in soluble excess in boiler water, no difficulty will be experienced. However, in addition to controlling the excess of these chemicals, it is necessary to reduce the initial contaminating materials to as low an amount as possible. Such materials are hardness (calcium and magnesium), iron, copper, silica and oxygen.

The hardness and silica may enter the cycle as condenser leakage, evaporator carryover, or through leaking valves on raw-water lines, bad operation of softeners or contamination of process or heating returns. Silica may also enter the system through fly-ash contamination of storage tanks. Iron and copper usually reach the boiler through the condensate or makeup having too low a pH value. With the carbon dioxide of the steam at a very low value the pH of the condensate should be high enough to reduce iron and copper pickup in the preboiler cycle to a minimum. A small amount of sulfite and phosphate added to the boiler water will react with any hardness or oxygen entering the boiler.

One new high-pressure unit now being installed will not use evaporators but will employ demineralized makeup water. This will reduce the hardness, silica and available carbon dioxide to very low amounts at a cost less than that of evaporation.

There is still some question as to the limiting concentrations of sulfite that may be carried as an oxygen scavenger in high-pressure boilers without affecting the steam. In some cases it is necessary to keep the sodium sulfite concentration below 10 ppm, whereas in others up to 60 ppm does not appear detrimental.

In a previous paper the author, in discussing the effect of pH of the steam on iron and copper pickup in the preboiler cycle, cited one station which, since September 1947, had been adding small amounts of ammonium chloride to keep the pH of the condensate between 8.8 and 9. Subsequent checks on this plant have shown the iron and copper pickup in the feedwater to be very much lower than before the ammonia treatment was started.

Atmospheric Pollution

A symposium on Atmospheric Pollution, under the chairmanship of **E. G. Bailey,** took up three hours on Friday morning and consisted of several papers.

In presenting the first paper, **Frank A. Chambers,** chief of Chicago's Smoke Inspection Department, reviewed the history of smoke abatement in that city which began with an ordinance in 1881. This was revised in 1907 to incorporate preventive measures through preinstallation approvals and to provide personnel for enforcement. In 1928, nuisances other than smoke were included, and in 1938, provision was made for yearly inspections of fuel-burning equipment above certain sizes. The 1948 revision required the plans to include equipment for the removal of solids and fumes that would otherwise be discharged from stacks.

The Chicago ordinance covers nuisances originating within a mile beyond the city limits.

While the earlier ordinances stressed penalties, the later trend has been toward preventing nuisances before they occur.

The second paper, entitled "Technical Aspects of Air Pollution Abatement," was given by **A. D. Singh** of Chicago, who outlined the avenues of approach to an analysis of the problem through employment of precipitation, centrifugal force, cyclonic or supersonic means. He discussed at some length pollution from sulfur fumes in which oxidation plays an important role in changing SO_2 to SO_3.

H. B. Lammers explained the purpose of The Coal Producers Committee for Smoke Abatement (Cincinnati, O.) as "stimulating interest in efficient utilization of coal and other fuels through proper methods of burning." It gives advice and consultation on smoke abatement upon request to any municipal officials, or interested organizations and individuals. To date the Committee has surveyed some sixty cities and made investigations in about a hundred more.

Following an explanation of the usual procedure employed, Mr. Lammers mentioned the A.S.M.E. Model Smoke Ordinance, or some modification of it, as often recommended where legislation is indicated; but in other cases a voluntary program will suffice. In fact, the Committee has gone on record as opposed to ordinances and the establishment of smoke departments in many small cities, preferring pressure by civic groups to bring about remedial action on the part of offenders.

Furthermore, there are no two cities alike and it is now becoming appreciated that the problem, in its entirety, is usually not smoke but one of atmospheric pollution that may be influenced by prevailing air conditions.

In conclusion, the speaker advised that a sensible

approach to the problem of air pollution must be based on the following:

1. Facts—not hearsay.
2. More attention to the three E's—engineering, equipment and education.
3. Economic factors.
4. Greater emphasis on administration than on legislation.
5. Acceptable standards.
6. Differentiation between pollutants that are nuisances only and those that are health factors.
7. All programs, to succeed, require public support.
8. The problem cannot be solved by the smoke inspector alone; he needs the combined help of experts in several fields, such as the engineer, the chemist, the combustion engineer, the doctor, the meteorologist and the city planner.

Methods employed by the Stanford Research Institute to investigate air pollution on the West Coast were described by Messrs. **Magill** and **Benoliel,** of that organization.

During the last ten years population of the three Pacific Coast states has increased between 40 and 50 per cent, accompanied by greatly increased industrial activity and more apparent atmospheric smog, particularly in the Los Angeles region. While very little coal is burned in this vicinity, the automobiles per capita exceed those of any other equivalent area; there are numerous domestic incinerators; and during periods of frost the smudge oil burners in citrus groves contribute greatly to the atmospheric pollution. Furthermore, weather phenomena and topography are factors.

The Stanford Research Institute began an investigation of Los Angeles smog about three years ago, and approached the problem with a view to ascertaining (1) where the polluting materials come from; (2) where they go; and (3) to what extent they are diluted by the time they reach ground level. The effect of stack height is apparent when it is realized that one pound of gaseous emission per hour from a stack 10 ft high will produce as high a concentration at ground level as one ton per hour issuing from a 400-ft stack. Also, it has been estimated that an increase of one degree F in temperature at the top of a stack is equivalent to adding $2^1/_2$ ft to the stack height.

Dispersion of fumes from moving vehicles depends upon surface wind. In Los Angeles, winds blow from the ocean toward the mountains during the day and reverse their direction at night; but wind movement during the night is usually not sufficient to carry a parcel of air across the city, as a result of which pollutants concentrate.

The principal adverse effects of air pollution in Los Angeles are eye irritation, poor visbility and occasional crop damage. The investigation revealed more than 40 contaminants regularly or periodically present and 7 others occasionally. Occurrence of eye irritation was found related to meteorological effects, even to the extent that it could be forecast two or three days in advance.

Analyses of the atmosphere in Los Angeles showed the pollution to range from 60 million to 600 million particles per cubic foot. These were classified into five general types: (1) carbon and metal particles which were responsible for 10 to 50 per cent decrease in visibility; (2) transparent, light scattering crystals; (3) small water soluble and oil-soluble particles, and oil droplets; (4) substances capable of forming moisture droplets in the air, such as sulfur trioxide; and (5) large soluble crystals made up mostly of sulfates, nitrates and chlorides. They account for from zero to 80 per cent of the decrease in visibility.

Central Heating Service

In a paper on "Steam Service from Central Stations,"[2] **G. D. Winans,** of The Detroit Edison Company, attributed the earlier unsatisfactory financial returns from central station heating to inadequate selling prices and lack of proper means for measuring the service; but more recently the situation has greatly improved.

District heating for business districts is a particularly favorable field, because of the high density of the load relative to the distribution investment. Also, the supply of steam together with electricity to manufacturing plants for process and space heating, under high use factor, gives promise of wider development and has proved successful in several localities. But, in general, district heating to detached residences has not been profitable, because of the relatively small quantities of heat required compared with the high cost of distribution; although a few such new installations are being made in connection with real estate developments.

Since it is usually impractical to return the condensate from customers' premises, makeup is very high and this is usually taken from the city mains.

In Detroit the cost of underground line construction ranges from $43 to $65 per foot, according to pipe size, and excavation cost represents a major portion of this cost.

Whether to generate electricity as a by-product of the heating steam must be decided in each individual case on the basis of local conditions, Mr. Winans pointed out, the decision depending largely upon the value of a kilowatt-hour at the location of the heating plant as compared with the total cost of so producing it. While the thermal advantage in passing all the steam through turbine-generators is well recognized, the commercial advantage is not always apparent. He then discussed factors influencing the amount of steam used for heating and told of measures followed by many companies to assist customers in obtaining maximum results from the steam purchased.

Coal-Burning Gas-Turbine Locomotive

John I. Yellott of the Locomotive Development Committee of Bituminous Coal Research, Inc., presented a progress report on an open-cycle gas-turbine for use in railroad service and designed to burn pulverized coal. Work on the development program began in the spring

[2] This paper will be reviewed in greater detail in a later issue.

of 1945, when projects were set up to study problems of coal handling, pulverizing, combustion and ash removal. By mid-1946 a pilot installation had been made at the Dunkirk, N. Y., plant of the American Locomotive Company, where it was possible to burn coal at rates up to 1000 lb per hr under pressures up to 60 psig.

Pilot-plant operation disclosed a number of major problems not apparent in small-scale operation at atmospheric pressure. The most serious one was that with ninety per cent combustion efficiency in cold-walled combustors, the carbon remaining in the ash burned vigorously in the fly-ash collectors.

In May 1949, erection was begun at the Dunkirk plant of a Houdry process gas turbine with provision to burn either oil or coal. Using the latter, the first stage of fly-ash removal is in a louver separator, after which the gas passes through a battery of American Blower type ST separators. At a firing rate of 1800 lb of coal per hour, the heat release in the combustor is approximately 750,000 Btu per hr per cu ft, or 6,000,000 Btu per hr per sq ft of cross-section area.

The combustor runs relatively cool and clear at the firing rate previously mentioned, and there has been very little slagging, virtually all of the ash appearing as a fine dry powder suspended in the products of combustion. Starting of the Dunkirk machine is by means of a steam turbine, operating through a reduction gear. Control is carried out by varying the amount of high-pressure air which is bled out, and the amount of fuel supplied. The speed of the unit is the primary variable, and the operator keeps it at a predetermined value by adjusting the fuel flow. Under normal conditions the speed remains constant despite variation in combustor outlet temperature of 25 degrees above and below the mean value.

Inspection after 150 hours of operation of the Houdry unit burning coal indicated no damage to the last row of blades. While a thin layer of dust adhered to the blades, there was no evidence of impairment of turbine performance.

Tests in which coal will be burned are soon expected to begin at Dunkirk on the 4200-hp gas-turbine power plant manufactured by Allis-Chalmers. This unit has already been tested on oil in Milwaukee, and if coal burning proves satisfactory, it will be installed in a locomotive, after which road tests will be undertaken.

Heat-Pump Cycle Performance

"Standards of Performance for Heat-Pump Cycles" was the title of a paper by **Professor J. F. Sandforth** of Iowa State College. Noting that it has often been implied that fifty years of refrigeration theory and experience can be applied equally well to the heat pump, the speaker termed this as an over-simplification of the situation. Since the heat pump will always be in competition with other heating systems, its economic development will largely depend upon raising its operating coefficient of performance, which is defined as the ratio of heating effect produced to the work required to produce this effect. The paper compares the performance of certain actual and ideal cycles now being used with a theoretical maximum standard of perfection.

By means of curves Professor Sandforth showed that vapor compression equipment presently available is capable of producing a coefficient of performance on the order of 3.5. Through refinements of this equipment, an improvement to a value of 5 might be expected, or in reference to the Carnot cycle (which has long been used as an ultimate efficiency standard for heat engines operating between a constant temperature energy source and a receiver) the increase would be from 42.2 to 60.2 per cent.

Role of the Business Man

The principal address at the "All Engineers Dinner" on Thursday evening was delivered by **Philip D. Reed,** chairman of the board of the General Electric Company and president of the International Chamber of Commerce. Taking as his topic "The Role of the Modern Business Man," Mr. Reed predicated his remarks on the present foreign situation. While heartily commending the Marshall Plan as a necessary expedient, he stressed the point that if we are going to be able to discontinue giving away billions of the taxpayers' money in foreign aid, we must be prepared to purchase more foreign goods to establish a dollar balance. "Handouts," he said, "are bad politically, morally and economically; and are bad for both the giver and the receiver."

Recent visits to a number of countries in western Europe had showed them to be tragically short of power, which of necessity is rationed in many cases for both industrial and domestic use. Since more electric power is essential to any program for increasing worker productivity, its unavailability today stands across the path of economic recovery.

Mr. Reed remarked that the electric power industries of Europe are very generally government-owned and operated; and that one needs no more convincing demonstration of the rightness of private utility ownership than to compare the conditions, costs and service available here and abroad. However, with the exception of England, he had noted a trend in most of these countries toward a relaxing of government control of business and encouragement of private enterprise.

Despite this, he observed, "We in the United States—although we have not gone as far toward Socialism as have many other countries—are, unhappily, still moving in that direction. Our government wants more, not less, central authority to direct and control the operations of business; it wants more authority to spend, and more taxes to finance its operations . . . . . . For the government to promise security is meaningless unless the economy of the country is sufficiently vital and productive to provide the products that will make that promise good. It is the people, not the government, who create wealth, and it is out of private production that government implements its programs of social betterment."

These things, Mr. Reed said, are well known to businessmen who have been keeping them very much to themselves, but there is now a growing interest in the best methods of imparting such information to large numbers of people in plants and communities. More and more companies are charging senior officers with responsibility for such educational work.

New boilers equipped with

HAGAN Controls and Meters

at JOHN B. STETSON CO.

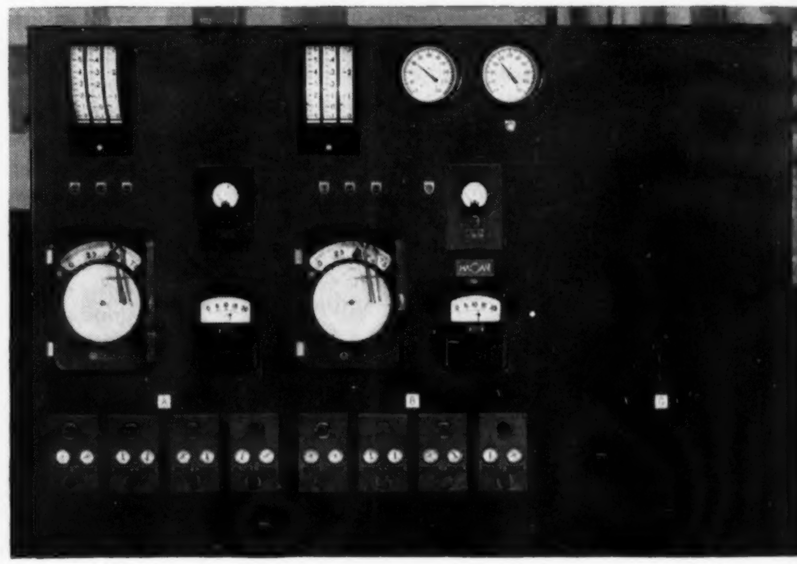
In 1865, John B. Stetson, hatmaker, occupied one small building in Philadelphia. Today, John B. Stetson Company is the world's largest manufacturers of fine hats for men and women, with plants in Philadelphia, New York, Danbury, Conn., and Brockville, Canada. Stetson hats have become part of the American legend,—in the ballads and stories of the southwest, every hero's hat is a Stetson.

Recent modernization of the Stetson Philadelphia plant included the installation of two oil fired boilers, with provision for a third—and this installation includes Hagan Combustion Control and Hagan Ring Balance Boiler Meters.

Steam is used in the hat making process, and to drive air compressors, vacuum cleaners and auxiliary equipment in the plant, and for heating the many large buildings which comprise the Philadelphia factory. The company also generates its own power.

The Combustion Control at the Stetson plant is a standard Hagan pneumatic system, including steam pressure furnace draft, and fuel-air ratio controls. Boiler meters are of the dual ring indicating, recording and integrating type, providing records of steam flow, air flow and stack temperature.

Hagan Controls and Hagan Ring Balance Meters are in service in plants of all types and sizes, in newly-built plants, and in modernized plants of long-established companies such as Stetson. For full information on these controls and meters, write to Hagan Corporation, Hagan Building, Pittsburgh 30, Pennsylvania.



Control Panel, showing three-pen indicating, recording and integrating Hagan Ring Balance Boiler Meters. Panel provides space for meter and control for a third boiler, to be installed later.

General view of boiler room. United Engineers and Constructors, Inc., Philadelphia, Pa., were engineers and contractors on this installation, working with Stetson engineers.

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THRUSTORQ FORCE MEASURING DEVICES
BOILER COMBUSTION CONTROL SYSTEMS
METALLURGICAL FURNACE CONTROL SYSTEMS

*Application of Gas-Turbine Technique to Steam Power**

This paper describes a condensing gas-turbine cycle with external combustion which utilizes orthodox gas-turbine and steam-turbine components so that the thermodynamic advantages of the two, in their respective temperature ranges, are combined to give a higher thermal efficiency than either alone.

By J. F. FIELD

Controller, S. E. Scotland Div., British Electricity Authority

EARLY attempts to adapt the turbine principle to air or gas were frustrated by compressor losses, but improvements in compressor efficiency, together with better high-temperature metals, have enabled the gas turbine to approach the efficiency of the steam turbine; although to achieve this it must operate at much higher temperature and with more effective high-temperature regeneration. On the other hand, it cannot utilize heat down to anything like the low temperature used by steam power. Therefore, most regenerative gas-turbine cycles are more efficient than steam in the upper temperature range and less efficient in the lower temperature range. However, now that the Rankine steam cycle has reached 1000 F, a given increment of temperature has much less effect on the steam turbine than on the gas turbine.

Hitherto, practically all steam power plants have worked on the Rankine cycle which, compared with the Carnot cycle, is progressively less efficient above the critical temperature of 705 F. Additions of heat above 1000 F have little effect on the Rankine efficiencies (see Fig. 6). In fact, heat consumption figures for steam turbines designed for 1500 psi and 1050 F, with 29 in. vacuum, show relatively small gain above 950 F.

The gas turbine, using a radically different mechanism from that of the steam turbine, continues to show substantial theoretical improvement up to a temperature of at least 2000 F. The reason is that the mean heat intake temperature is much nearer the maximum than is possible with the Rankine cycle and, since efficiency is virtually independent of pressure, the advantage can be used in small units where the losses would be prohibitive with the Rankine cycle.

The elementary gas turbine mechanism, Fig. 1, consists of an air compressor, a pressure combustion chamber, a gas expander (turbine), and a regenerator. In the temperature-entropy diagram the ideal positive work is represented by *ABCDEFGH* and the ideal negative work by *ABGH*. This cycle has the disadvantage of large negative work; and unless there is intercooled compression, heat is rejected at constant pressure often at a temperature above 400 F. Thus a single-heating-stage gas turbine has to operate with an initial temperature some 400 to 500 deg F higher than the steam turbine in order to obtain the same overall thermal efficiency. One stage of reheating, combined with one stage of intercooling, reduces this difference to between 200 and 300 deg; but it is hardly worth while to reduce the difference any further.

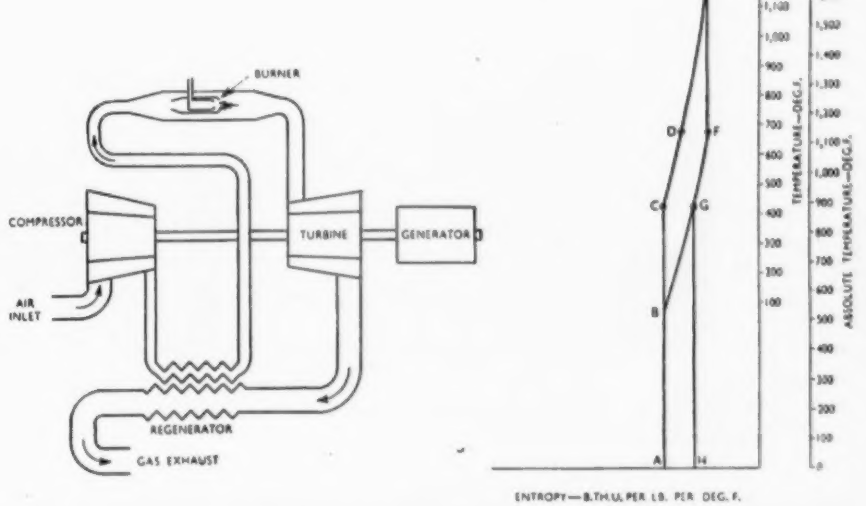


Fig. 1—The elementary gas-turbine cycle

* Excerpts from a paper before a joint meeting of the Institute of Mechanical Engineers and the Institution of Electrical Engineers, London, England, February 24, 1950.

If superheated steam could be used in a gas-turbine mechanism over the upper range of temperature, where the Rankine cycle is ineffective, and at the same time the advantages of the Rankine cycle at the lower temperature end were retained, indications are that a higher efficiency than either the regenerative gas turbine or the regenerative Rankine-cycle steam turbine would be had.

Steam is amenable to this arrangement if the gas-turbine mechanism is provided with an externally fired superheater, in place of the internal combustion chamber, and if a spray-type desuperheater be added. Such an arrangement is indicated by Fig. 2 in which dry saturated steam, at say 400 psi, passes through the surface regenerator, gaining heat from the turbine exhaust steam, and is then raised in the superheater to around 1200 F. It then expands through the turbine and passes through the regenerator, a portion being bled off equal to the weight of spray water required to bring the remainder back to the wet condition (point B) where it can enter the compressor and be compressed back to the starting point.

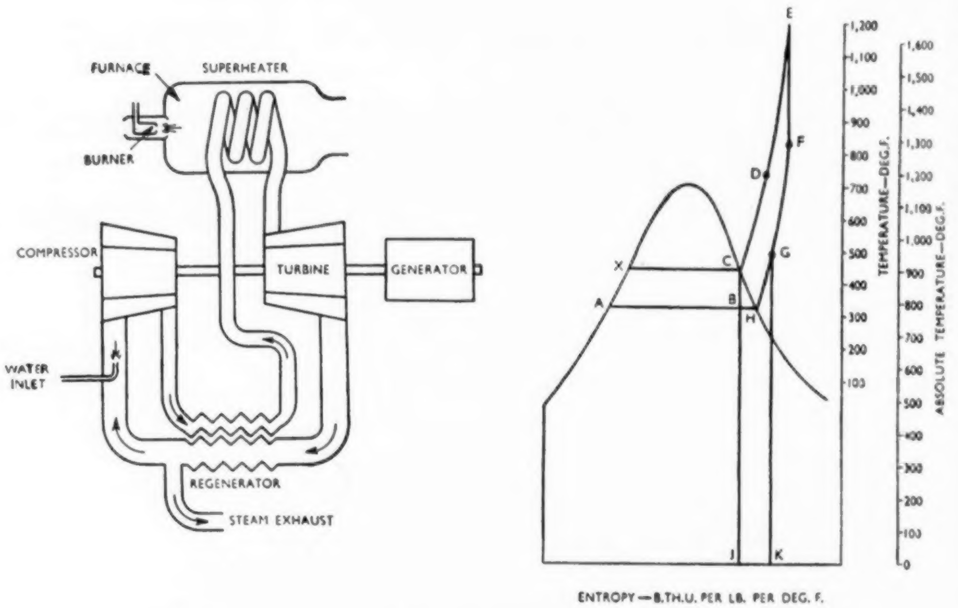


Fig. 2—Modification of gas-turbine cycle for use with steam

Alternatively, to avoid wet compression the steam is desuperheated to the point H and the remainder of the water is injected into the compressor, stage by stage, so that compression takes place entirely in the superheat region just above the line HC. The ideal positive work is represented by $AXCBA$, this being generally a smaller proportion of the positive work than in a comparable noncondensable gas cycle.

Steam bled off below the regenerator, at say 100 psi, may be passed through a Rankine cycle as suggested by Fig. 3, and the resulting condensate used in the desuperheater. There is a small gap in available heat drop between the lower temperature end of the gas-turbine cycle and the upper temperature end of the Rankine cycle. This diminishes with reheating in the gas-turbine cycle and with feed heating in the Rankine cycle.

Fig. 4 indicates what should be obtainable with a long-

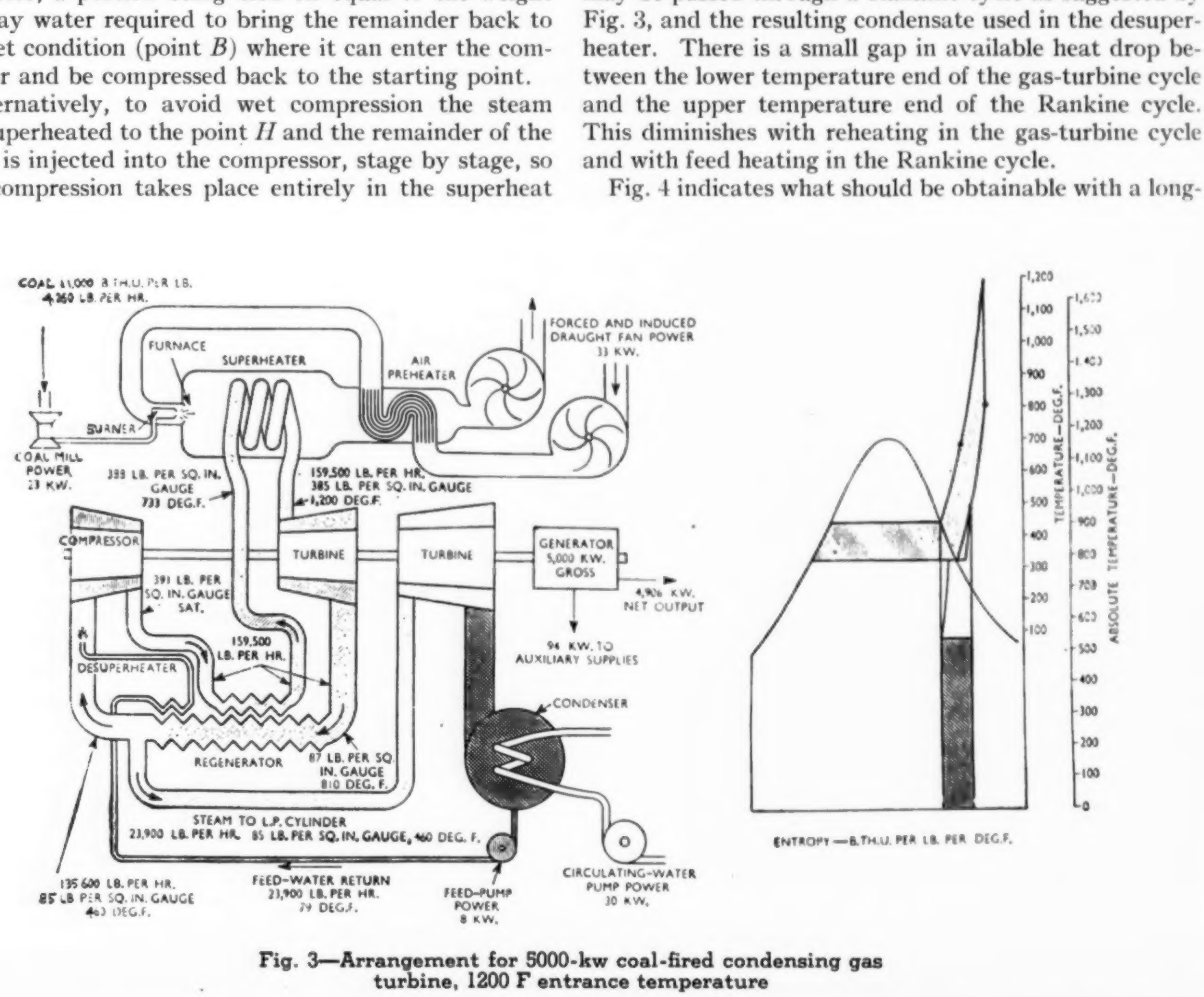


Fig. 3—Arrangement for 5000-kw coal-fired condensing gas turbine, 1200 F entrance temperature

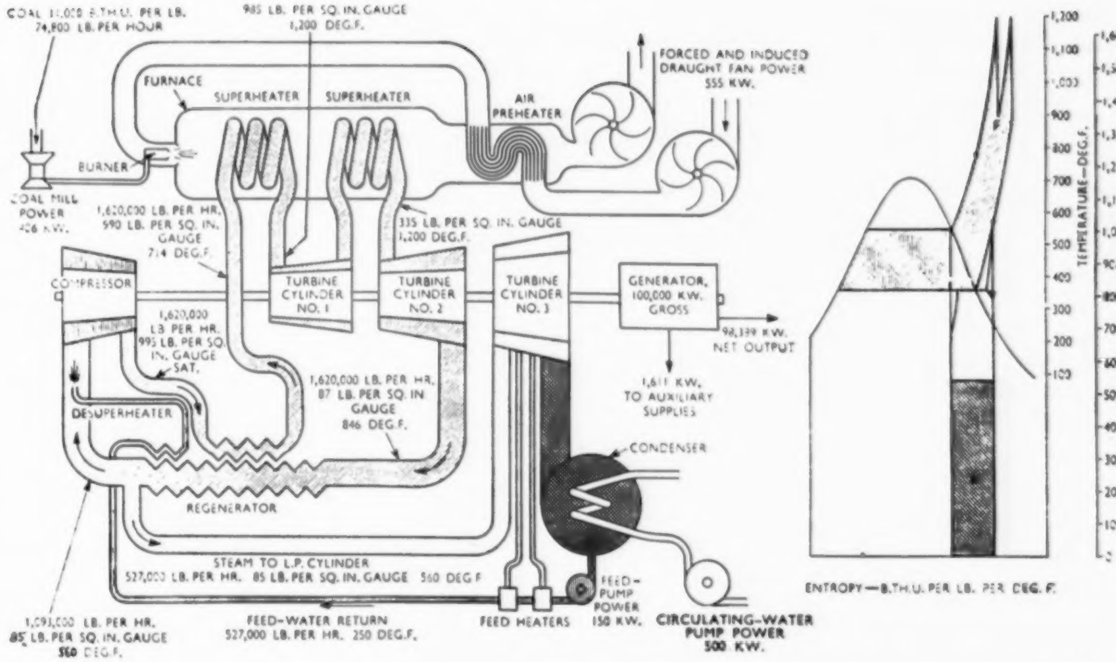


Fig. 4—Suggested arrangement for 100,000-kw, coal-fired, condensing gas turbine designed for long life and having a net plant "send-out" efficiency of 40.85 per cent with 1200 F entrance temperature

life plant of large size, and Fig. 5 a plant employing higher temperatures that at present are suitable only for short-life aircraft gas turbines. Minor improvements in component efficiencies should then yield a "send-out" efficiency of 50 per cent of the gross calorific value of the coal burned.

As compared with an internal-combustion gas turbine, this cycle has the disadvantage of a boiler efficiency of 85 to 90 per cent; but, apart from the decisive advantage of using almost any kind of fuel irrespective of ash content, the output from the lower Rankine cycle element much more than neutralizes that disadvantage.

Gas-turbine technique can also be applied to the production of process steam.

Calculated Efficiencies

Calculated results for selected examples are shown in Figs. 6 to 8. Fig. 6 indicates that under favorable circumstances, for large units, the gas-turbine arrangement

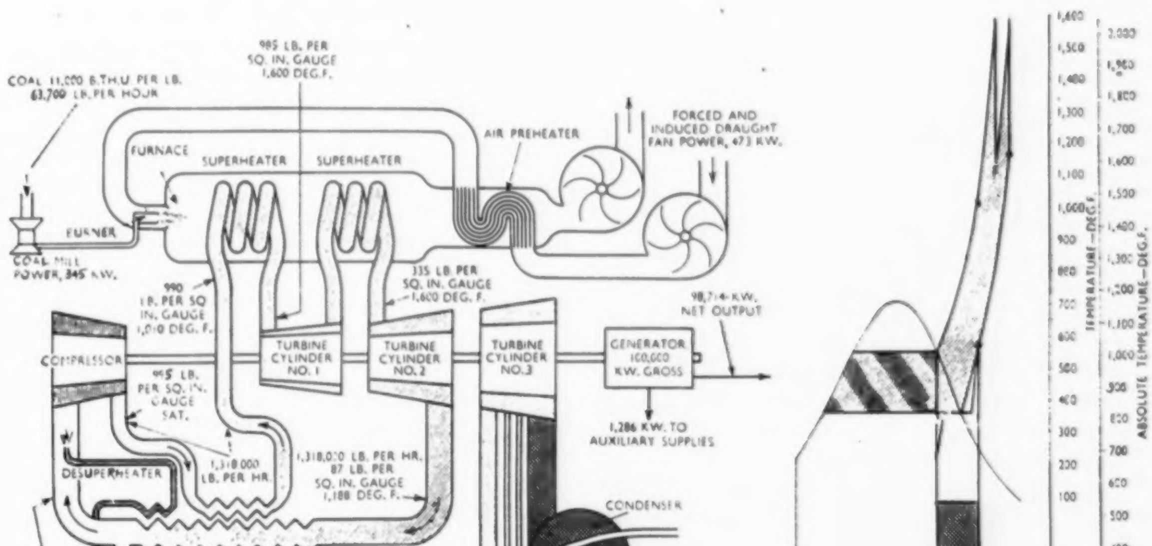


Fig. 5—Layout for 100,000-kw, coal-fired, condensing gas turbine designed for short life with 1600 F entrance temperature and having 48.2 per cent net plant "send-out" efficiency

should approximate the performance of the Rankine cycle at 850 F; and the single-heating-stage gas-turbine arrangement would probably equal the performance of the large size Rankine cycle set at an inlet temperature of about 950 F. Although small single-heating-stage gas-turbine sets of this kind would have a performance not greatly inferior to the large sets with two-stage heating, it is virtually unthinkable commercially to apply the Rankine regenerative cycle to small sets operating at the range of temperatures shown in Fig. 6. Therefore, irrespective of size, but particularly with reference to the smaller sizes, the improvement in thermal economy made possible by the gas turbine cycle is very great.

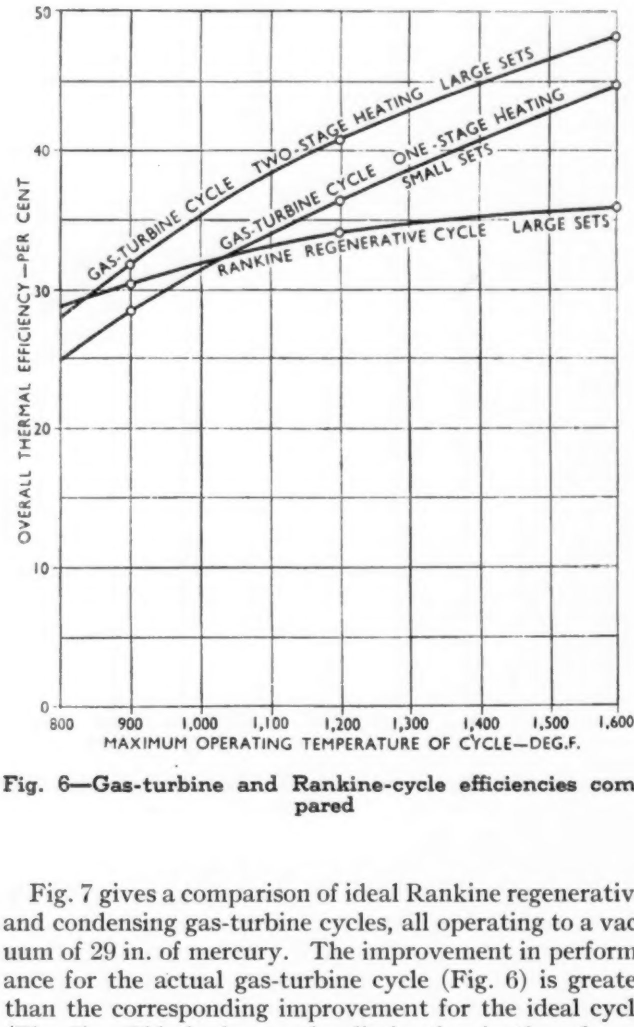


Fig. 6—Gas-turbine and Rankine-cycle efficiencies compared

Fig. 7 gives a comparison of ideal Rankine regenerative and condensing gas-turbine cycles, all operating to a vacuum of 29 in. of mercury. The improvement in performance for the actual gas-turbine cycle (Fig. 6) is greater than the corresponding improvement for the ideal cycle (Fig. 7). This is due to the diminution in the adverse effect of compressor losses and the corresponding steady improvement in the thermodynamic efficiency of the gas-turbine cycle with rise in temperature.

Fig. 8 indicates the theoretical heat drops available with a perfect gas-turbine mechanism as compared with a perfect Rankine-cycle mechanism.

Normal gas-turbine practice involves a considerable mean temperature difference between the air and gas, where the constant-pressure temperature-entropy lines are almost parallel. In the modified cycle described, a considerable gradient is available, even with a theoretically perfect heat-exchanger, and there should be an early limit to increase in area for gain in efficiency. There is every prospect for a very economical regenerator.

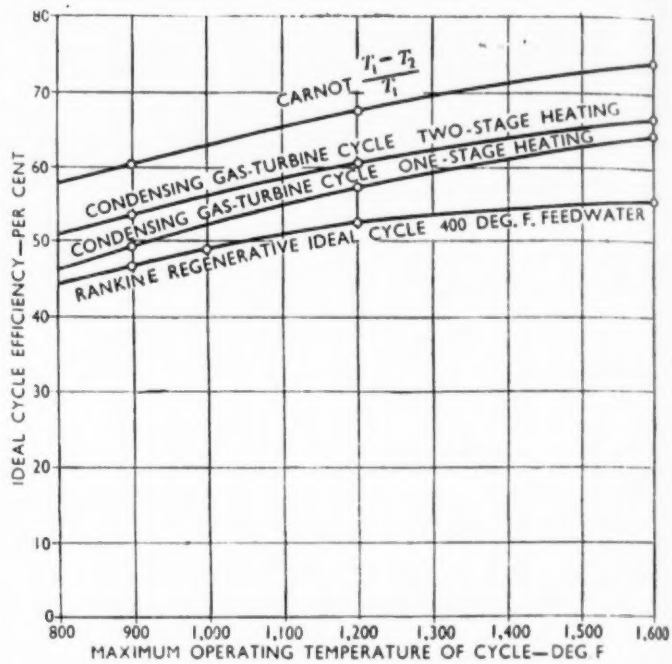


Fig. 7—Ideal Rankine regenerative and gas-turbine cycle efficiencies

In connection with combustion, regeneration, and heat-exchange efficiency, there is wide experience with both pulverized coal and oil firing for electric power production. Regenerative feed heating is already employed for temperatures approaching 500 F, with the corresponding preheating of combustion air to at least the same degree to attain the desired boiler efficiency. The application of gas-turbine technique at 1200 F necessitates regenerative steam heating to 750 F, which would require only a moderate development of existing air preheater technique to maintain desired boiler efficiency.

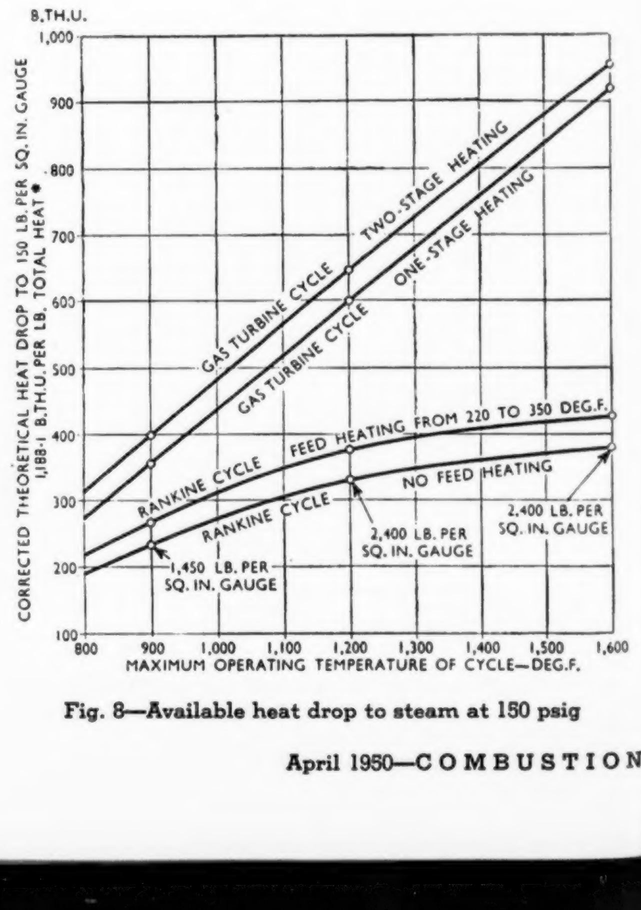


Fig. 8—Available heat drop to steam at 150 psig

Conditioning Makeup by High-Temp., Sodium Ion-Exchange Excess Calcium, Hot Lime-Zeolite Process

By F. N. KEMMER
Cochrane Corporation

This is a relatively new method for treatment of boiler makeup which can also be adapted to existing hot-process softener installations to improve the quality of the effluent. Described is the "excess calcium" method of hot-lime treatment which can be employed to produce low effluent alkalinity to hold down CO_2 concentration in the steam.

ION-EXCHANGE as a process for treating boiler makeup has heretofore been limited in its scope to low-temperature operation, because of the inability of the older siliceous, phenolic and coal-base types of ion-exchangers to withstand the aggressive attack of water at elevated temperatures and relatively high pH values.

With the development of the sulfonated styrene resin exchangers able to resist attack at high temperatures in a caustic environment, the power plant designer and operator is provided with a new route toward production of high-quality boiler makeup which will be followed in many cases in preference to older paths. Not only is hot-process ion-exchange a new process in itself, but also it will exert a strong influence over existing processes, such as the hot-lime softener which it will supplement as a second-stage treatment.

Table 1 indicates various types of sodium exchangers. the approximate period in which they were developed, and the maximum temperatures and pH environments for which they are suited. The tabulation indicates that this new process has been delayed awaiting the development of a stable high-temperature, high pH ion-exchanger.

TABLE 1

Exchange Material	Period of Adoption	Usual Max Temp, Deg F	Usual Max pH
A. Siliceous			
Cochranex CG & CGH (Greensand)	1915–1925	100	8.5
Cochranex CSL & CSP (Synthetic Gel)	1925–1930	100	8.0
B. Carbonaceous-Coal Base			
Cochranex CCA	1935–1940	120	9.5
C. Resinous-Phenolic			
Cochranex CRQ & CRF	1935–1945	120	8.5
Cochranex CRM	1935–1940	120	9.3
D. Resinous-Styrene			
Cochranex CRW & CRZ	1945–1950	250	10.5

Single-Stage, High-Temperature Sodium Ion-Exchanger

As a single-stage treatment, high-temperature ion-exchange is finding application as a means of recovering heat and conserving water, by treating hot water from heat-exchange equipment that might otherwise be discharged to waste. Many plants presently using sodium zeolite softeners to treat cold water will benefit by replacing existing zeolite beds, limited to handling cold water, with Cochranex CRW or CRZ, to enable them to treat water from surface or jet condensers or cooling water from heat-exchangers which the existing beds could not handle because of their temperature restrictions. Such plants should study the economy of this measure, balancing the extra cost of temperature-resistant resin beds, piping changes and modification in pumping against the savings which would accrue to the value of the heat or the water recovered. Even in the event that heat recovery is not possible, as in the case of plants having an excess of exhaust steam, the saving in water alone will in many instances justify the subsitution as a conservation measure.

The single-stage, ion-exchange process will also find application to the treatment of condensate contaminated by in-leakage of hard water. There are a number of plants where such contaminated condensate is presently being treated by hot-phosphate treatment, one of which has been reported in the technical literature. The sodium ion-exchange process, using cheap salt for regeneration, will effect an economy in such a situation.

Two-Stage Lime Zeolite Treatment, Hot Process Versus Cold Process

As a second-stage process to follow a lime treatment unit, high-temperature ion-exchange will find wide application. Although lime is the cheapest reagent for hardness reduction, it does not permit low hardness residuals where appreciable noncarbonate hardness is present and is, therefore, supplemented by soda ash, phosphate reagents or both, to provide a finished water of acceptably low hardness. High-temperature sodium ion-exchange treatment will generally displace these other supplementary treatments, since salt, used in the regenerating of the sodium exchanger, is generally cheaper than soda ash for hardness removal and considerably cheaper than any of the phosphate reagents conventionally used either in a second-stage sedimentation and reaction unit or in the boiler itself.

In the hot-process treatment, if the magnesium in the raw water is too low to accomplish the desired silica reduction, substitution of dolomitic lime for high-calcium hydrated lime, or addition of magnesium oxide, may be practiced to obtain these results. Further silica reduction in the cold-process system, however, would be expensive, since excessively high dosages of the silica-adsorbing reagents would be required to reduce silica to even as low as 3 ppm, and the reagents required would cause an increase in dissolved solids in the effluent. It is well established that silica adsorption efficiencies vary directly with the temperature of operation.

In addition to its advantage over cold process, lime-zeolite in silica reduction, hot-process lime-zeolite exhibits an economy in cost due to several factors:

a. It produces an effluent having a turbidity below 10 ppm without the need of a coagulant.
b. Lower hardness after lime saves salt.
c. No acid or hexa-meta-phosphate is required to protect the zeolite against after-reactions as is true with cold process.

Two-stage cold-process treatment, however, will still find application in plants where only part of the lime-softened water is further treated through a sodium zeolite softener for boiler makeup, with the bulk of the effluent being used at low temperatures for process water or for such service as cooling-tower makeup.

Table 2 is typical of results to be expected of a two-stage, hot-process lime-zeolite system. Since salt, used in regeneration of the second-stage sodium ion-exchanger,

TABLE 2—TWO-STAGE LIME-ZEOLITE TREATMENT, HOT PROCESS VERSUS COLD PROCESS (RESULTS OBTAINED WITHOUT SODA ASH)

Constituent	Ppm	Raw Water	Hot Process First Stage (Lime)	Hot Process Final Effluent (Na_2Z)	Cold Process First-Stage (Lime-Alum)	Cold Process Final Effluent (Na_2Z)
Ca	as $CaCO_3$	120	88	0–1	60	0–1
Mg	" "	55	2	0–1	50	0–1
Na	" "	25	25	113	25	133
Total cations	" "	200	115	115	135	135
HCO_3	" "	110	0	0	0	0
CO_3	" "	0	20	20	35	35
OH	" "	0	5	5	0	0
SO_4	" "	55	55	55	65	65
Cl	" "	35	35	35	35	35
Total anions	" "	200	115	115	135	135
Hardness	as $CaCO_3$	175	90	0–2	110	0–2
M. O. alkalinity	" "	110	25	25	35	35
Silica	as SiO_2	10	1	1	8	8
Total dissolved solids*		246	146	146	181	187
pH		7.3	10.0	10.0	9.8	9.8

Treatment and Operating Costs

Reagent	Cost, ¢/Lb	Hot Lb/1000 Gal	Hot ¢/1000 Gal	Cold Lb/1000 Gal	Cold ¢/1000 Gal
Lime hydrate (90%)	0.8	1.13	0.91	0.95	0.76
Hexa-meta-phosphate	12	..	..	0.04	0.48
Salt	0.8	1.57	1.26	1.92	1.54
Alum. sulfate	1.8	..	..	0.18	0.32
Total			2.17		3.10

NOTE: Cost of supplementary boiler phosphate reagent not shown, since this would be substantially the same for either hot- or cold-process treatment. Assumed costs of chemicals must be checked with local supply sources.
* Calculated as final sodium salt.

will reduce non-carbonate hardness as cheaply as will soda ash normally used for this purpose in the sedimentation tank, the elimination of soda ash from this process is economically justified. The result of eliminating soda ash, aside from the cost of treatment, is the production of an effluent of appreciably lower alkalinity.

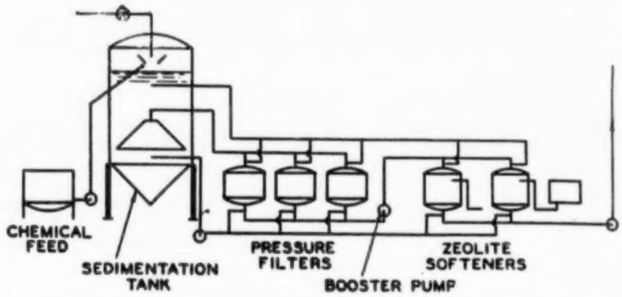


Fig. 1—Two-stage, hot-process system—sedimentation plus filtration plus ion-exchange

Hot Lime-Soda Zeolite Versus Hydrogen-Sodium Zeolite

Note that this method of hot-process treatment produces a carbonate alkalinity in the effluent of 20 ppm as $CaCO_3$, or lower, which would produce less than 9 ppm CO_2 in the steam at 100 per cent makeup. This is consistent with the CO_2 concentration in the steam produced by most of the existing hydrogen zeolite-sodium zeolite plants producing a blended bicarbonate alkalinity of 10 ppm as $CaCO_3$. By this method of operation, therefore, the hot-process softener competes favorably with the split-stream dealkalizing plant and has the advantage over the latter system of reducing silica and producing low alkalinities without the use of acid. The comparative results and costs of treatment are given in Table 3.

TABLE 3—HOT LIME ZEOLITE VERSUS H_2Z-NA_2Z (RESULTS OBTAINED WITHOUT SODA ASH)

Constituent	Ppm	Raw Water	Hot Process First Stage (Lime)	Hot Process Final Effluent (Na_2Z)	Cold Process, H_2Z-Na_2Z
Ca	as $CaCO_3$	160	143	0–1	0–1
Mg	" "	70	2	0–1	0–1
Na	" "	40	40	183	168
Total cations		270	185	185	170
HCO_3	as $CaCO_3$	110	0	0	10
CO_3	" "	0	20	20	0
OH	" "	0	5	5	0
SO_4	" "	90	90	90	90
Cl	" "	70	70	70	70
Total anions		270	185	185	170
Hardness	as $CaCO_3$	230	145	0–2	0–2
M. O. alkalinity	" "	110	25	25	10
Silica	as SiO_2	15	1	1	15
Total dissolved solids*		342	243	243	242
pH		7.4	10.0	10.0	6.8

Treatment and Operating Costs

Reagent	Cost ¢/Lb	Hot Lb/1000 Gal	Hot ¢/1000 Gal	Cold Lb/1000 Gal	Cold ¢/1000 Gal
Lime (90%)	0.8	1.23	0.99	..	..
Salt	0.8	2.55	2.04	3.6	2.88
Sulfuric acid (66 deg)	1.0	..	..	1.48	1.48
Total			3.03		4.36

NOTE: Cost of supplementary boiler phosphate reagent not shown, since this would be substantially the same for either hot- or cold-process treatment. Assumed costs of chemicals must be checked with local supply sources.
* Calculated as final sodium salts.

Excess Calcium Causes Low Alkalinity

This method of hot-process operation, eliminating soda ash to obtain low carbonate alkalinity, may be termed the "excess calcium" treatment as contrasted with the conventional "excess soda" or "excess carbonate" treatment, usually practiced to obtain low calcium effluent hardness.

In quantitative chemical analysis, the solubility product of slightly soluble compounds, such as calcium carbonate, is defined as the product of the cation and anion concentrations. For calcium carbonate the expression is:

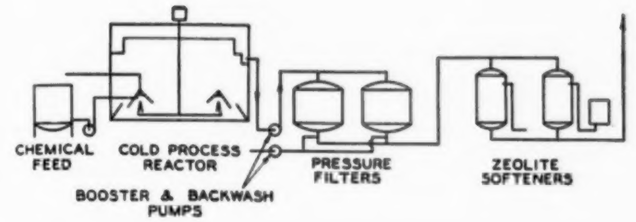


Fig. 2—Two-stage, cold-process system—sedimentation plus filtration plus ion-exchange

$$[Ca^{++}] \times [CO_3^{--}] = K \text{ (solubility product)}$$

This is a hyperbolic function, illustrated by Fig. 3.

With soda ash treatment, the carbonate radical $[CO_3^{--}]$, is maintained at relatively high values, 45 to 60 ppm as $CaCO_3$, to hold down the calcium concentration to about 18 to 20 ppm as $CaCO_3$. Additional carbonate, introduced as excess soda ash, will result in even lower calcium residuals. With "excess calcium" treatment, the calcium concentration, $[Ca^{++}]$ is held at relatively high values, no attempt being made to reduce the non-carbonate hardness, and this results in an appreciable lowering of the carbonate alkalinity.

Thus, it is apparent that high-temperature ion-exchange supplements the conventional hot-process softener and actually widens its field of application by introducing a means to produce low effluent alkalinity economically without the use of acid. Not only does elimination of soda ash from the first-stage treatment improve overall results by lowering the effluent alkalinity, but it also simplifies the chemical treatment since only one chemical, lime, is required in the first stage. With but a single reagent to adjust, automatic control on the basis of pH becomes practical. In the treatment of water supplies of a variable nature, lime can be fed to the first-stage unit on the basis of average conditions and the over- and undertreatment resulting from variations in the raw water analysis will be partially compensated by the second-stage sodium ion-exchanger, which will continue to produce an effluent of zero hardness.

Hot-Process Lime-Zeolite Versus Two-Stage Hot Lime-Soda Ash Phosphate

An outstanding field of application of high-temperature ion-exchange will be in competition with the second-stage phsophate sedimentation tank. Here, the economics of the process are as shown by Table 4 in which an index of the cost of reagent per unit hardness removal is given.

TABLE 4—COST INDEX OF VARIOUS REAGENTS FOR HARDNESS REMOVAL

Reagent	Formula	Cost, \$/Ton	Cost, ¢/1000 Gal per GPG Hardness	Cost Index
Lime (90%)	$Ca(OH)_2$	\$ 16	0.095–0.190*	1.0–2.0*
Soda ash	Na_2CO_3	30	0.23	2.4
Salt	NaCl	16	0.24	2.5
Phosphoric acid (75%)	H_3PO_4	110	0.69	7.3
Disodium phosphate (anhyd.)	Na_2HPO_4	150	1.19	12.6

* NOTE: The economy of using lime varies from minimum cost when removing calcium as the carbonate to maximum cost when removing magnesium as the hydroxide.

In Table 4 salt for regeneration of the sodium ion-exchange is based on a dosage of 0.30 lb per kilograin. This low dosage is utilized by virtue of the fact that the styrene resin is operated below its full available exchange capacity. The rather low influent hardness will produce long periods between regenerations even though the full exchange capacity is not realized. At high temperatures there is no sacrifice in effluent quality at this low regeneration level because of the high rate of reaction, increased ionic mobility and a decrease in the water viscosity and surface tension, permitting the ions to migrate into the structure of the resin particles.

Fig. 4 illustrates a two-stage hot-process softener in which lime and soda ash are introduced to the first stage, for the bulk of hardness removal, followed by addition of disodium phosphate to the second-stage for reduction of the hardness to zero by the soap test, with filtration of the second-stage effluent. A comparison with Fig. 1 indicates the simplicity of the lime-zeolite system over the lime-soda-phosphate hot-process softener. The results of treating the raw water of Table 2 by these two methods of treatment is shown in Table 5.

TABLE 5—HOT-PROCESS TREATMENT: LIME-ZEOLITE VERSUS LIME-SODA ASH PHOSPHATE

Constituent	Ppm	Water	Lime-Zeolite: First Stage (Lime)	Lime-Zeolite: Final Effluent (Na_2Z)	Lime-Phosphate: First Stage (Lime-Soda)	Lime-Phosphate: Final Effluent (PO_4)
Ca	as $CaCO_3$	120	88	0–1	18	0–1
Mg	" "	55	2	0–1	2	0–1
Na	" "	25	25	119	115	139
Total cations	" "	200	115	121	135	141
HCO_3	as $CaCO_3$	110	0	0	0	0
CO_3	" "	0	20	20	45	45
OH	" "	0	5	5	0	0
SO_4	" "	55	55	55	55	55
Cl	" "	35	35	35	35	35
PO_4	" "	0	0	6*	0	6
Total anions	" "	200	115	121	135	141
Hardness	as $CaCO_3$	175	90	0–2	20	0–2
M. O. alkalinity	" "	110	25	25	45	45
Silica	as SiO_2	10	1	1	1	1
Total dissolved solids		246	146	146	177	185
pH		7.3	10.0	10.0	9.8	9.8

Treatment and Operating Costs

Reagent	Cost, ¢/Lb	Lime-Zeolite: Lb/1000 Gal.	Lime-Zeolite: ¢/1000 Gal.	Lime-Phosphate: Lb/1000 Gal.	Lime-Phosphate: ¢/1000 Gal.
Lime	0.8	1.13	0.91	1.13	0.91
Soda ash	1.5	..	..	0.81	1.22
Salt	0.8	1.57	1.26	..	..
Disod. phosphate†	7.5	0.05	0.38	0.20	1.50
Total			2.55		3.63

* Calculated as final sodium salts.
† NOTE: Supplementary phosphate added directly to boiler drums.
Assumed cost of chemicals must be checked against local supply sources.

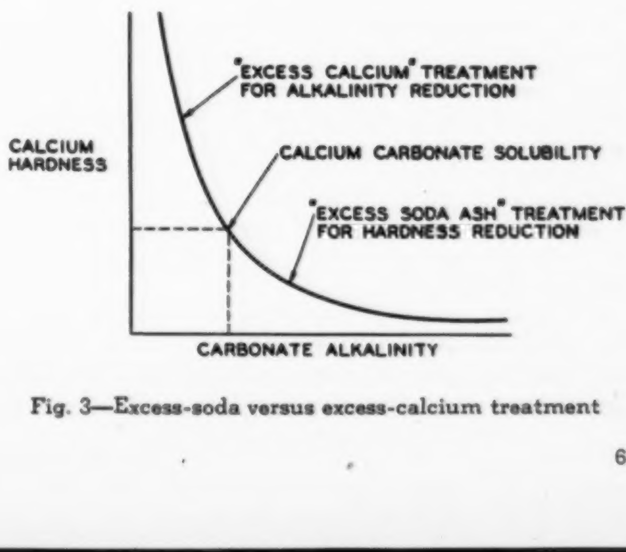


Fig. 3—Excess-soda versus excess-calcium treatment

In this tabulation, the economy of the hot lime-zeolite process is outstanding. The chemical cost comparison also holds for a single-stage, hot lime-soda softener followed by phosphate injected directly into the boiler drums, since the phosphate required by the latter system is essentially the same as for the hot lime-soda-phosphate softener. Note the lowered alkalinity caused by elimination of soda ash from the first-stage treatment as compared with hot lime-soda-phosphate treatment.

Ion-Exchange as an Addition to an Existing Plant

Pilot plant studies of high-temperature ion-exchange have been based on direct treatment of hot lime-soda softener settled water effluent. However, the inviting prospect of simply replacing existing pressure filter beds with a high-temperature zeolite should be viewed cautiously. In the cold, zeolite materials are conceded to be unable to handle turbidities much in excess of 10 ppm in downflow operation. The fact that this turbidity limit is imposed on ion-exchange beds is evidence that any turbidity whatsoever should be avoided as a guarantee of trouble-free operation.

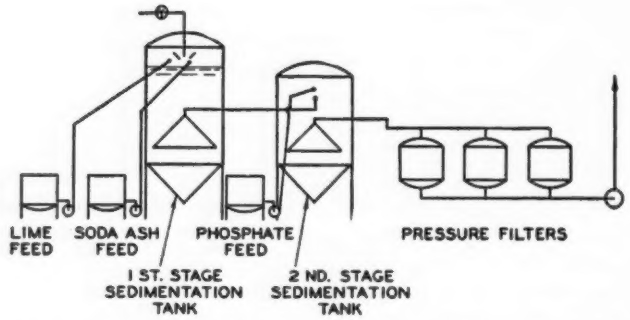


Fig. 4—Two-stage, hot-process sedimentation—lime-soda plus phosphate plus filtration

Past practice with cold-process treatment has proved the soundness of filtration between sedimentation and ion-exchange units, since a clear supply of water prevents fouling of the exchanger beds, permits higher operating rates, eliminates the need for frequent backwashing of the beds between regeneration periods and allows proper classification of the beds during backwash. Furthermore, on unfiltered water, break-through of hard water at unexpected times may be experienced. The practice of filtering the influent to zeolite softeners has long been standard for both industrial and municipal installations and should be respected regardless of the temperature at which the ion-exchange beds operate.

It is true that the bulk of the turbidity from a hot-lime softener is comprised of calcium carbonate and magnesium hydroxide. These compounds could be dissolved by occasional acid cleaning of the exchange beds if the ion-exchange units were used to filter and soften the hot-lime softener effluent directly. However, silica and organic materials not readily soluble in acid are also occluded with the turbidity and these will gradually plug the pores of the resin granules if turbidity is permitted to reach the exchanger beds.

As a general rule, it will be found of economic advantage to install both filters and separate ion-exchange units, since this arrangement allows both the filters and the ion-exchange units to operate at maximum loading, which results in a saving in volume of ion-exchange resin. Were the ion-exchange units required to operate as filters, it would be necessary to use ratings applied to such service. Since filtration rates are generally less than 50 per cent of the loading permitted on ion-exchange beds in gallons per minute per square foot, more than twice the zeolite bed volume would be required by using the resin in a dual-filtration ion-exchange rôle, compared to the zeolite bed volume necessary with individual filters and ion-exchange units.

There will be some instances where plants considering the second-stage ion-exchange process to follow an existing hot-lime softener have no additional floor space for expansion and must of necessity replace filter beds with ion-exchange resin beds. In such cases, a thorough study of plant operation should be undertaken to determine the following factors:

a. What measures can be taken to insure having the sedimentation tank deliver less than 10 ppm turbidity effluent at all times?
b. Can the sedimentation tank operate at an overload to provide regeneration water?
c. If not, what water is available for backwash, brine injection and rinse?
d. How can existing pressure filters be modified to adapt them to ion-exchange operation?
e. What provisions can be made for stand-by operation to permit acid treatment of the exchanger beds on a regularly scheduled basis?
f. What will be the pressure drop conditions after conversion to ion-exchange operation?
g. What modification will be required to existing pumping operations?
h. Will it be possible to backwash each unit as frequently as every eight hours without upsetting the operation of the hot-process sedimentation tank?

These questions require careful study by engineers who are thoroughly aware of the thermodynamic and hydraulic factors involved in the design of the original hot-process plant so that the addition of the zeolite plant will operate successfully to meet the local conditions.

Facts and Figures

A new molybdenum lubricant for bearings has been reported as three times as effective as oil.

As early as 1822 Jacob Perkins began a series of experiments with steam up to 1400 psig.

Hydrogen cooling of electric generators was first applied in this country in 1926.

The coal miners' working day is $6^1/_2$ hr underground, five days a week, with paid travel and lunch time.

The normal summer load of the Pentagon Building in Washington, D. C., is around 28,000 kw, which includes power for air conditioning.

Representatives from twenty-seven different countries will participate in the forthcoming World Power Conference in London, July 10–15, at which 159 papers are scheduled for presentation.

Importation of foreign oils into the United States is reported to be at the rate of 885,000 bbl per day, over half of which is fuel oil.

The first steam turbine to be installed in an American central station was a 2000-kw unit placed in service at Hartford, Conn., just fifty years ago.

Properties of Metals at Elevated Temperatures—I

By G. V. SMITH

Research Metallurgist, U. S. Steel Corporation

Widespread interest in the possibilities of higher steam temperatures for power generation makes this article particularly timely. Part I considers the matter of metal strength at elevated temperatures, working stresses that may be applied, characteristics of creep, the relation between stress and time for rupture, and a typical design chart for a stainless steel. Effects of non-constant stress and temperature, metallurgical variables, microstructural and surface changes, and scaling and corrosion will be discussed in Part II, scheduled for the May issue.

THE properties of metals at elevated temperature are of interest for two principal reasons. First, metals are frequently formed or shaped while heated; in such processing, the metal is at elevated temperature for a relatively short time. Secondly, metals are used in extended service at elevated temperatures as in power generation, oil refining or chemical processing. This paper considers principally those properties that are of interest in the use of metals for service at elevated temperatures.

Among the properties of interest in the service of metals at elevated temperatures may be mentioned the following broad categories:

1. Strength.
2. Other physical properties such as thermal expansivity or conductivity, elastic moduli, etc.
3. Resistance to scaling or other corrosive attack.
4. Changes in microstructure occurring during service and the effect of these on the properties.

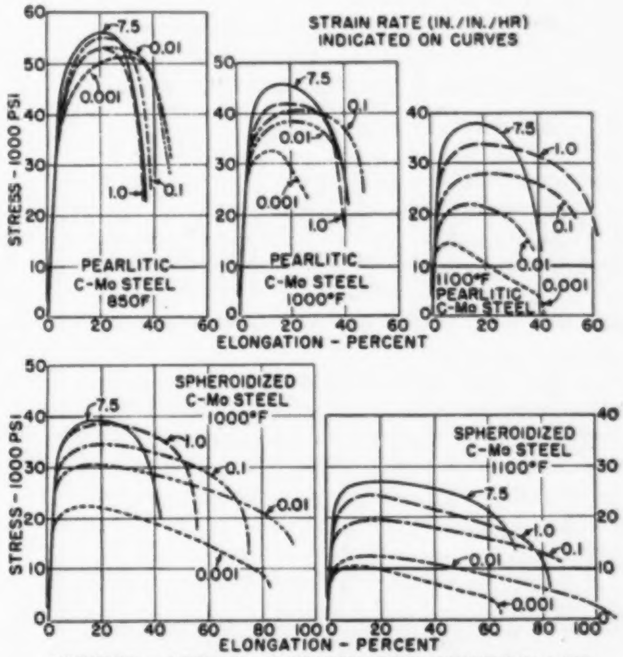
Working Stresses

Although many properties are of interest in the use of metals at elevated temperatures, one overshadows all the rest. This is the matter of the strength and of the working stresses to be applied.

In the use of metals at or near room temperature, the working stresses employed for structures subjected to essentially static loading, as contrasted with dynamic or fatigue loading, are usually selected on the basis of the properties shown in the familiar tension test. The working stress is generally selected to be less than the elastic limit, and when the metal is subjected to this stress during service, it undergoes the corresponding elastic strain; on unloading this strain disappears.

Effect of Temperature

With increasing temperature, the load-elongation diagram is displaced to lower level. This feature, as well as several others, may be noted in the illustration which



STRESS-STRAIN CURVES FOR CONTROLLED STRAIN RATE TENSILE TESTS OF PEARLITIC AND SPHEROIDIZED CARBON-MOLYBDENUM STEEL AT 850, 1000 AND 1100 DEG. FAHR.

shows the effects not only of temperature, but also of strain rate, on the load-elongation curve of 0.5 per cent molybdenum steel. This is a material that has been widely employed in the past for steam pipe service. The steel was tested not only in the condition in which it generally entered service, but also in a prespheroidized condition, which simulates the microstructural changes that occur during service. This treatment, it may be noted, causes a decrease in strength. In regard to temperature effect, the tensile strength of the pearlitic material, for a strain rate of 7.5 in. per in. per hr, decreases continuously from about 56,000 psi at 850 F to about 38,000 psi at 1100 F.

The effect of strain rate becomes increasingly important with increase of temperature; at 1100 F, for the pearlitic

* A talk before Process and Metals Division, Metropolitan Section ASME, March 7, 1950.

material, the tensile strength decreases from about 38,000 psi to about 15,000 psi with change of the strain-rate from 7.5 to 0.001 in. per in. per hr.

With decrease of strain-rate at any temperature there is frequently observed to be a change in the character of the fracture. At fast rates (short times for fracture), fracture of a ductile metal is accompanied by "necking in," but at slow rates (long times for fracture), fracture is abrupt. When one prepares and examines longitudinal sections through the fractures, he finds that the individual crystals or grains of which the metal is comprised are severely distorted in the direction of stressing and that the path of fracture is across the grains, i.e., transgranular, for fast rates of stressing, whereas grains remain as in the initial annealed metal, essentially equiaxed, in the slow strain-rate fractures, and the path of fracture is between the grains, i.e., intergranular. As the time for fracture increases, and the type of fracture changes from transgranular to intergranular, the total extension preceding fracture generally, but not always, diminishes to small values. Thus, fracture frequently gives no warning that it is impending. While the change from transgranular fracture to intergranular has been stated to occur with increasing time for fracture, it also will occur with increasing temperature at constant strain rate.

Creep

Since with increasing temperature or decreasing rate of straining the whole load-elongation curve is depressed, it is obvious that the permissible stresses to be employed for long-time service at elevated temperature must be less than at room temperature. Early designers assumed that all that need be done was to make a tension test at the temperature of interest, and then to use the same criterion of working stress as at room temperature. However, to their surprise, they observed that their structure did not undergo simply the immediate strain associated with loading, but instead, continued to deform with time. Thus, they encountered creep, i.e., continuing deformation under essentially constant stress conditions.

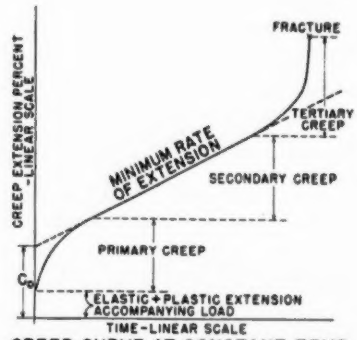
It was then considered that more sensitive extensometers should be employed so as to determine a limit below which creep would not occur. Unfortunately, this limit diminished the more refined the measurement, and was generally observed either to be nonexistent or so low as to make design quite uneconomical. When this was recognized, the modern viewpoint of design for creep service came into existence, namely that the occurrence of creep should be recognized, and design stresses be so chosen as to limit it to tolerable values.

Characteristics of Creep

With this brief background, let us consider the characteristics of creep phenomena in some detail.

On application of the load, as shown in the characteristic creep curve at constant load and temperature, there is an immediate elastic extension along with some plastic extension. The further course of deformation then is such that the rate first decelerates, then remains substantially constant and minimum, and finally accelerates to fracture, or as it is frequently called, rupture. These several periods are often labeled primary, secondary and tertiary creep, as indicated. While the idealized course of creep is illustrated, the actual curves may appear quite different. The load may be so low that for practical purposes creep ceases, whereas if the temperature is relatively high, the primary stage of creep may be virtually absent. Moreover, changes in microstructure may occur and significantly affect the course of the creep curve. In extreme cases, negative creep, that is, contraction under tensile load, may occur. But it is to be emphasized that in all cases the end result of creep is fracture.

Also illustrated are the two most important considerations in the choice of working stresses. First, by the very occurrence of creep, the engineer is faced with the fact that his vessel or part will change in dimensions with time, and he therefore must choose the working stress so that this deformation will not exceed during the expected life some permissible amount depending upon the application. Thus turbine blades may be designed for a life of 20 years in which time a total change in dimensions of 1 per cent may be tolerable. In contrast, a deformation of 5 per cent may not be excessive in a steam pipe, designed for the same period.



CREEP CURVE AT CONSTANT TEMPERATURE AND LOAD-(SCHEMATIC)

The other principal consideration in the choice of working stresses is that since the end result of creep is fracture, the design stress must be chosen so that fracture does not occur within the contemplated service life. Limitation of the total creep to 5% or even 1% does not necessarily insure that fracture does not occur, since the time for fracture does not bear any unique relation to the amount of deformation at fracture.

It is important to emphasize that there must, in theory be a limited expected life; also, that when creep occurs, an indefinite life cannot be anticipated since with time, either or both of two things may happen: (1) the strain which can be tolerated will be exceeded, and (2) fracture may result.

Thus the two principal considerations are that one should choose the working stress such that (1) some specific amount of creep is not exceeded; and (2) actual fracture does not occur. Intimately tied in with these limitations is the problem of the need for extrapolation in most applications, inasmuch as it is physically as well as economically impossible to conduct laboratory or acceptance tests for applications involving 20 years of service. How, then, shall the working stress be chosen within these restrictions? The limitation of fracture is much the more easily effected. One simply makes creep tests at different stresses, determines the corre-

sponding fracture times and relates these graphically. The relation thus obtained is relatively simple.

The relation between deformation and time is somewhat more difficult to evaluate, owing to the complex shape of the creep curve. According to the creep curve, the total deformation at any time earlier than the beginning of tertiary creep is given by the summation of the quantity C_0, which is the intercept of the minimum rate slope on the ordinate axis, and the product of the minimum creep rate and the time, or

$$C_t = C_0 + C_m t$$

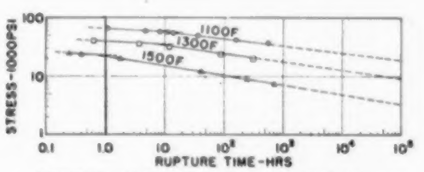
where C_t is the total creep at time t, C_0 is the intercept, C_m is the minimum creep rate and t any time less than the beginning of tertiary creep. Thus to calculate the total deformation for various stresses, one requires the relations between stress and the quantities: intercept C_0, minimum creep rate and time for beginning of tertiary creep. These relations are obtained by testing a number of specimens each at different stress.

Let us examine the nature of these relations in terms of actual experimental data obtained on 18 Cr–8 Ni–Mo stainless steel (A.I.S.I. Type 316).

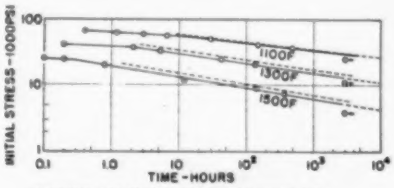
Stress Versus Rupture Time

The relation between stress and time for rupture plotted to log-log coordinates, for most but not all metals, results in one or two straight lines. The change in slope is quite generally encountered if the range of temperature and deformation rate (time for rupture) are great enough, and seems to be associated with the change in type of fracture described earlier. Once the second slope has been established, there is little reason, on the basis of available experimental data, to expect a further change. Thus extrapolation to times beyond those which can be experimentally studied in the laboratory may be made with some confidence.

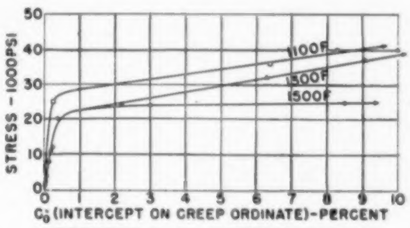
The relation between stress and time for beginning of tertiary creep is generally observed to lie parallel to and below that for time to rupture. It will be recalled that the time for beginning of tertiary creep limits the calculation of total creep according to the means previously described.



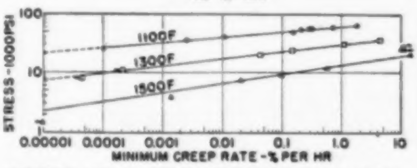
STRESS VS RUPTURE TIME; 18-8-Mo



STRESS VS TIME FOR BEGINNING OF TERTIARY CREEP (SOLID LINES)
STRESS VS RUPTURE TIME (DASHED LINES)
18-8-Mo



INTERCEPT C_0 VS STRESS; 18-8-Mo



STRESS VS MINIMUM CREEP RATE; 18-8-Mo

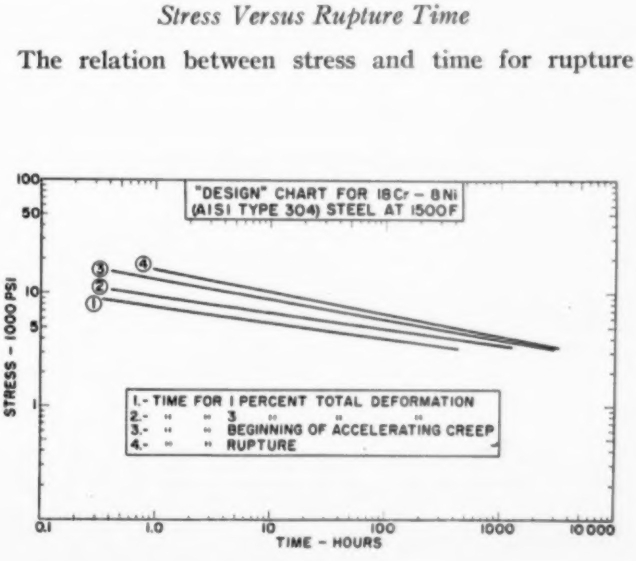
The intercept C_0 varies with the stress. For the data shown, the relation is comprised of two linear portions of quite different slope which merge with one another. Whether such is generally the case is not known since relatively few data of this nature are yet available.

The relation between stress and minimum creep rate is also linear on log-log coordinates for most materials, and thus suited to at least limited extrapolation.

Design Charts

The data shown permit, within their limitations, the selection of working stresses such that (1) no more than a specific permissible strain will occur, and (2) fracture will not occur. It is of course first necessary to define the permissible maximum strain and the contemplated service life.

These data can be summarized in a useful and increasingly popular manner by the preparation of so-called "design charts." In such a chart, stress is plotted against the times to attain various total deformations, such as one per cent and three per cent and against the times for beginning of tertiary creep and for rupture. The data in the illustration are for 18 Cr–8 Ni stainless steel (A.I.S.I. Type 304).



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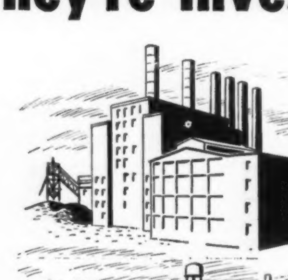
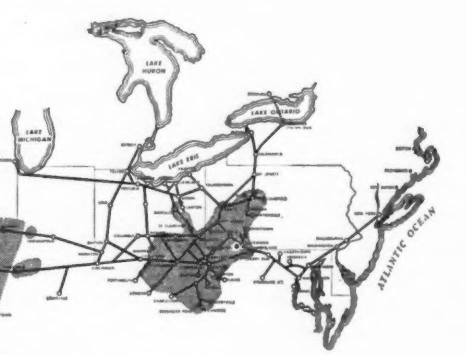




LAKE HURON
LAKE MICHIGAN
LAKE ERIE
LAKE ONTARIO
ATLANTIC OCEAN

Progress and Costs of Synthetic Fuel

A BROAD advance toward competitive liquid fuels from oil shale and coal has been announced by Secretary of the Interior Oscar L. Chapman in his 1949 annual report to U. S. Congress on achievements of the Bureau of Mines in synthetic liquid fuels research and development.

Appraising progress in terms of estimated product cost, a primary factor considered by private industry in making new investments, Secretary Chapman said that refined products now could be produced from oil shale and coal at actual costs averaging 7.3 and 10.8 cents a gallon, respectively. If a profit of 6 per cent on the average unamortized capital investment is added, plus income taxes, the wholesale price for products at the plant would average 9 cents a gallon for those from oil shale and 14.5 cents for those from coal. Further reductions he believed certain as knowledge is extended.

Capital investment now required for a plant producing 10,000 bbl a day of crude shale oil, or 8840 bbl daily of refined products, is estimated at $41,381,000, including facilities for mining, retorting, and refining. This is an average of $4138 for each daily barrel of crude oil capacity or $4681 per daily barrel of finished product. Such a plant would produce jet and diesel fuel primarily, plus a small amount of fuel oil. The removal of sulfur and nitrogen is no longer a serious problem, the report said, and motor gasoline may be produced readily by slight modification of the refining process.

Production costs for shale-oil products even now are within or very near the competitive range of those from petroleum. Another problem remains, however, a market for the products. The oil-shale area of western Colorado is sparsely populated and could not absorb the entire output of a 10,000-bbl-a-day plant. Construction of a 50,000-bbl-per-day pipe line could provide transportation to large consuming centers at a total cost of less than 1 cent a gallon, but would require the outputs of five 10,000-bbl-per-day plants for capacity operations. This means that a large capital outlay of approximately $240 million would be necessary for plants and pipe line at the start of commercial development.

The estimated capital investment for a modern coal-hydrogenation plant producing 30,000 bbl a day is $246,800,000 or approximately $8227 for each daily bbl of product capacity. High-octane gasoline would be the principal product and by-products would include liquefied petroleum gases and phenols, for which there is a growing demand. As coal-hydrogenation plants are highly flexible, the product distribution readily could be changed to include aviation gasoline which would improve the profit possibilities. Aviation fuel (100/130 grade), now quoted in the coal regions at 16 to 18 cents a gallon, could be sold at the plant for 16.6 cents a gallon wholesale as compared to the 14.5 cents a gallon that would be required for automotive gasoline from coal. Process improvements now under development in the laboratory are expected to reduce these figures.

Oil from Coal

At Louisiana, Mo., major activities in the new coal-to-oil demonstration plants shifted from design and construction to completion of equipment installations, testing, and initial operations.

Design work has been finished for the second demonstration plant, an 80- to 100-bbl-a-day gas synthesis plant, and construction was estimated to be 70 per cent complete last December 1. This plant will convert to oil by a modified Fischer-Tropsch process.

At Bruceton, Pa., the work of the coal-to-oil laboratories and pilot plants was centered on the development of new or improved processes for the synthesis of liquid fuels from the gasification products of coal, and for the direct hydrogenation of coal. Two coal-hydrogenation pilot plants also were placed in operation, one for the liquid-phase and one for the vapor-phase step.

At Gorgas, Ala., the Alabama Power Company and the Bureau of Mines undertook their second field-scale experiment in the underground gasification of coal in March 1949. Gases produced by burning unmined coal under controlled conditions offer a potentially low-cost fuel for generation of electric power as well as materials for conversion to liquid fuels.

Here there has been no difficulty in maintaining combustion, and about 3000 tons of coal have been burned. No limit yet has been found as to the quantity that can be consumed from an area surrounding a given, initial entry. Equipment and the air-gas inlets and outlets have operated successfully as installed.

Although gas quality has not been emphasized in initial operations, the calorific value of the product gas has been high enough at times to make it combustible. However, owing to air bypassing through void spaces underground and the subsequent combustion of the product gas before removal from the system, the energy content of the coal as brought to the surface has been largely in the form of sensible heat. This could be used, of course, for generating steam at the system outlets. A producer gas of good quality apparently is being made along the burning coal ribs, but it has not yet been possible to recover such gas. Void spaces causing the air bypass difficulty are being blocked by introducing fluidized sand into the original entry through small boreholes from the surface.

At Morgantown, W. Va., in the Bureau's Synthesis Gas Production Laboratories, the problem of producing cheaply the carbon monoxide and hydrogen required in synthetic liquid fuels manufacture was under attack from another quarter. Test runs in a small pilot plant indicated that

this unit will gasify virtually any type of coal, regardless of its ash or sulfur content. Gasification tests in a larger unit, conducted at about 3600 F., were made with lower oxygen consumption than any previously reported for other plants. Gasification of the total carbon content of the coal was very satisfactory, ranging from 70 to 90 per cent.

Oil from Oil Shale

Near Rifle, Colo., in the Bureau's experimental mine on the Naval Oil-Shale Reserves, low-cost methods and equipment were developed for mining one of the world's greatest fuel deposits—the Green River shale formation of Colorado, Utah and Wyoming.

The average production rate maintained during a 4-week run was 148 tons of shale per man-shift of underground labor, or 116 tons per man-shift of total labor. It is believed that no other underground mining operation has approached these averages. The direct mining cost, excluding depreciation, general office expense, and overhead, was 29 cents per ton of shale. Total production for the 20 operating days was 32,560 tons.

Hydrogenation was found to be the most practical method of refining shale oil to reduce sulfur and nitrogen contents and produce good quality liquid fuels. In studies of the catalytic cracking of shale-oil fractions, the yields that can be obtained in using each of several commercial cracking catalysts were determined. Evidence was found that much of the color and gum formation in shale-oil products is attributable to the presence of nitrogen compounds of the pyrrole type, and pyrrole.

In addition to the foregoing, a small plant at Peoria, Ill., operated by the Bureau of Agricultural and Industrial Chemistry, continued work to establish the manufacturing steps and costs of its process for producing alcohol and other liquid fuels from such agricultural residues as corncobs and the hulls of cottonseed oats, and rice.

Code Chairman Honored

Henry B. Oatley, chairman of the A.S.M.E. Boiler Code Committee and retired vice president of The Superheater Company, was honored with the degree of Doctor of Engineering by Stevens Institute of Technology on February 8.

An alumnus of the University of Vermont, Mr. Oatley spent his first ten years following graduation as a test engineer with the American Locomotive Company and then joined The Superheater Company which he served successively as mechanical engineer, chief engineer, vice president in charge of engineering, and subsequent to retirement from the last-mentioned position he became consulting engineer.

During these forty years he presented many technical papers before various engineering societies and railroad clubs, and has been responsible for numerous inventions relating to superheaters and other devices for locomotive use.

Long active in the A.S.M.E. of which he is a Fellow, Mr. Oatley has for some years headed up its most important Boiler Code Committee.

Trends in the Small Industrial Steam Plant Offer Opportunities for Young Engineers

Young engineers may find increasing opportunities in power plants of smaller industries which do not now have engineering departments, according to S. E. Friedeberg, vice president of the Franklin Engineering Corporation. Speaking at a recent meeting under the sponsorship of the Junior Group of the Metropolitan Section of the A.S.M.E., Mr. Friedeberg emphasized that young men must be willing to "get their hands dirty" and offer convincing information to management that investments in steam plant improvement can produce a return equally favorable when compared to other possible capital expenditures. In other words, proposals for steam plant improvement must be indicative of first-hand observations of power plant operation, evidence good engineering, and be economically sound.

Excessive Steam Costs

Many industrial power plants with capacities on the order of 50,000 lb per hr produce steam at costs that are excessive by comparison to average standards of today. They are operated, in all too many cases, by manual labor, the amount of which could be substantially reduced if modern handling methods were utilized. By contrast to the thousands of dollars which some plants may spend annually to develop and maintain production-cost systems, the same plants often have little or no knowledge of steam costs and may have no means of measuring or recording fuel quantity, steam production, and combustion conditions. Engineering talent applied to the small industrial plant, according to Mr. Friedeberg, should produce profitable returns.

Plant Expansion

Ofttimes expansion of existing steam plants—and sometimes even the construction of a new power plant—is undertaken without obtaining the necessary basic engineering data. The result is that such plants either lack adequate capacity or represent an excessive investment with corresponding fixed charges that cause steam costs to be high.

Engineers must approach problems of the small steam plant on an individual and impartial basis. To allow preconceived ideas suited to one plant to carry over to the design of another is to invite difficulty. Seldom, if ever, will two plants have the same load conditions, and it should be obvious that such things as water quality and available personnel vary widely.

Sight should not be lost of the fact that steam in a small plant is not generally produced under the supervision of highly trained personnel. However, the young engineer may be one means of improving operating practices and introducing money-saving practices of record-keeping and planned maintenance. It should be kept in mind that equipment to record steam production cost involves an investment on the order of one half of one per cent of the annual fuel bill for a typical industrial steam plant.

Whenever production facilities of an industrial plant undergo a major expansion, additional service facilities, including steam, are required. At such times a complete survey of existing steam generating facilities should be carried out, making certain that the engineer undertaking the study has all pertinent data and information relating to the expansion program. Studies of this sort may indicate the replacement of existing boilers with those of larger capacity. Sometimes a new boiler plant may be required, in which case the quantity of the steam required and the characteristics of the steam load will be important governing factors.

Fluctuating Steam Loads

For plants with widely fluctuating steam loads, special design provisions must be made. Unless such installations can supply peak loads at a constant predetermined steam pressure, they do not fulfill their basic function. No attempt should be made to enter upon the design or construction of this particular type of plant without a complete study of existing and contemplated steam requirements. It is advisable to evaluate separately steam requirements for heating and processing. In connection with the design it will be well to study carefully the fuel supply situation and make provision for possible future changes.

Educational programs designed to improve firing of fuels can be the source of much plant improvement. With mechanical firing equipment and a simple system of combustion control, plant efficiency may be increased. This is in keeping with use in industrial power plants of developments originally brought about for central station practice. Thus less "muscle" and more "brain" may be employed in industrial steam plants, bringing that phase of operations to the same high level of efficiency as the other departments of the industrial plant.

Conclusion

Mr. Friedeberg's closing words were: "The engineer who possesses knowledge of the art of steam generation in addition to his basic training can render valuable service to industrial plants generating steam for processing and other services. "The day may not be too far distant when the position of the attendant in the small steam plant will be added to the ever-growing list of white-collar jobs."

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

An Introduction to the Engineering Profession

By J. G. McGuire and H. W. Barlow

Professional guidance is a subject in which the practicing engineer should retain an active interest. As one who may be responsible for employing technical personnel, and certainly as one who will have increasing contact with younger engineers as the years roll by, the experienced engineer can benefit by a knowledge of contemporary practice in guiding vocationally undecided youth to specific professional fields. To the person who is out of contact with the guidance movement, "An Introduction to the Engineering Profession" should prove to be a good indicator of current practice in counseling high school and college students.

The book is divided into four parts: The Profession of Engineering, Major Fields of Engineering, The Supporting Studies, and Engineering Problems. Most of the chapters have selected-reading and visual-aid listings, and the book as a whole is attractively illustrated with appropriate line cuts and some outstanding photographs showing engineering installations. The last part of the book explains techniques of engineering problem solution, provides an introduction to slide-rule use and includes typical illustrative problems of an elementary nature.

There are 224 pages and 93 illustrations, and the book sells for $3.50.

Elements of Thermodynamics and Heat Transfer

Edward F. Obert

As might be inferred from the title, this book stresses the elements rather than the practical application of thermodynamics, flow of fluids, thermochemical calculations and heat transfer; but the book is unique in its inclusion of many figures showing engineering examples of the principles being discussed.

This book is designed for a one- or two-semester college course and the portion on thermodynamics is a condensation of another book by the same author. A very desirable feature is a complete list in the front of all symbols except those pertaining to the single chapter of Heat Transfer which are listed elsewhere. Another good feature is the Survey of Dimensions and Units which will be appreciated by those older engineers who may have occasion to review this subject.

The section on Thermodynamics includes chapters on Fundamental Concepts, the First Law, the Reversible Process, the Second Law, Properties of Fluids, Characteristics of Gases, and Approximate Calculations for Real Gases. Following these are chapters on The Flow of Fluids, Mixtures of Gases and Vapors, Thermochemical Calculations (combustion), Power Cycles and Refrigeration.

In the chapter on Heat Transfer the working equations and charts for convection and radiation are mainly from McAdams and Hottell, respectively.

In common with most text books on heat transfer is the inclusion of tables or charts in the appendix covering the physical properties of fluids, but the omission of any statement as to whether the values given were used in determining the numerical constants of the heat transfer equations recommended. Also missing, although needed in the solution of most practical heat transfer problems, is a theory or method of how to calculate the physical properties of gaseous mixtures.

The book has more than 125 figures associated with the text and six charts in the appendix.

There are 372 pages and the book sells for $4.50.

Heat Power Fundamentals

By C. M. Leonard and V. L. Maleev

Although it may be difficult for the experienced mechanical engineer to recall his undergraduate introduction to heat-power engineering, on occasion he may do well to bring to mind the viewpoint of the young student. This is particularly true should he be called upon to evaluate or recommend one or more textbooks from among the many intended to cover the field of heat power.

Messrs. Leonard and Maleev have prepared their text for students taking a first course in heat-power engineering, with or without previous instruction in thermodynamics. For reasons justified both by the complexity of the steam power plant and its relative importance as a source of power generation, nearly eighty per cent of the text is devoted to that type of installation. Beginning with a chapter on the Vapor Power-Plant Cycle, development of the book progresses through considerations of thermodynamics and steam properties, and the steam engine and steam turbine as principal prime movers. Successive chapters follow on Heat Removal and Condensing Equipment; Water Conditioning, Heating and Pumping; Steam Generation: Boilers and Superheaters; Fuels and Combustion; Heat Generation: Furnaces and Fuel-Burning Equipment, and Draft and Draft Equipment; and Vapor Cycles. There are concluding chapters on the Internal-Combustion-Engine Power Plant, Gas-Turbine Power Plants, and Mechanical Refrigeration.

It should be apparent that the text follows a logical order of development, the effectiveness of which is increased by the inclusion of numerous instructive line drawings indicative of recent advances in the power plant art. Each chapter includes appropriate problems, many with answers, and a bibliography with numerous up-to-date references to authoritative books and technical articles. All in all, the book appears to serve adequately the functions for which it was written.

There are 596 pages and the price is $5.75.

Development of Aircraft Engines

By Robert Schlaifer

Development of Aviation Fuels

By S. D. Heron

These two studies of relations between government and business, bound into a single volume, explain some of the problems in insuring that technical research and development is actively prosecuted in times of war and peace. Though devoted primarily to the aviation and petroleum industries, the work raises questions that are worthy of attention in many areas of business and industry.

For engineers in the power field there is an exceptionally informative chapter on the background of the development of gas turbines, and throughout the book references are made to metallurgical improvements enabling equipment operation at extreme temperature conditions.

Part I provides some valuable information on government-industry relationships in carrying out engineering developments. Chapters entitled Government Conduct and Technical Control, Development at Private Risk, Development Directly Supported by the Government, and The Problems of Radical Innovations are quite worthy of serious study by those having management responsibilities in research and development. Part II brings out the rôle of competition for technical prestige as it applies to the liquid fuel industry and traces the interrelationship of fuel and engine development over the last few decades.

Regarding the authors, Dr. Schlaifer has a background combining experience as a physicist with that of a historian and is at present a member of the faculty of the Harvard Business School. Mr. S. D. Heron has been a consulting engineer specializing in aircraft-engine development and has been associated with both government agencies and private companies in the United States as well as in European countries.

The book contains 754 pages and sells for $5.75.

Welding Metallurgy—Iron and Steel

If there is one subject which is of universal interest to welding-minded people it is welding metallurgy. This explains the large attendance at the educational lectures (on welding metallurgy) at the A.W.S. Annual Meeting in 1948, the

preference for this subject as a topic before local groups throughout the United States and the record sales (30,000 copies) of the first edition of *Welding Metallurgy* by Prof. O. H. Henry and Dr. G. E. Claussen.

After three years of work, this new Second Edition by Mr. G. E. Linnert, of Armco Steel Corporation, is now ready. It is new and larger, contains more information, has an improved arrangement and presentation and is even more handsome.

The new information—150 more pages and a total of 203 illustrations—covers new processes such as inert-gas metal-arc welding and includes more information on some of the materials such as the stainless, heat-resisting and stainless clad steels.

Deliberate effort has been made to keep the language simple; where technical metallurgical terms have been used they have been defined.

The basic theory of metallurgy is described in the first few chapters of the book for those having no previous knowledge of the subject; later chapters cover the welding metallurgy of different materials and the effect of different elements on welding. These chapters should be of interest to all readers.

The arrangement has been changed making the book easier to read and handier to use. An extensive index has been added for ready reference. A list of suggested reading has been included at the end of each chapter containing suggested sources for more detailed information on the subject covered by that chapter. The usefulness of the book as a school text or for individual home study has been increased by grouping a series of questions on each chapter, at the end of the book.

Much thought has been given to appearance. A better paper has been used, the illustrations have been redrawn to make them uniform and the material has been arranged so that there is a pleasing balance between text and illustrations. All of this improves the readability as well.

Published by the American Welding Society, the Second Edition covers 505 pages, is cloth bound, illustrated and indexed. Price, $2.50 per copy postage paid.

ECPD Seventeenth Annual Report

The Seventeenth Annual Report of the Engineers' Council for Professional Development gives an encouraging across-the-board picture of what the engineering profession is doing to improve the competence of its members and to make engineering work more rewarding in personal satisfactions. It deserves a careful reading by all engineers who are interested in the betterment of the profession.

The principal work of ECPD is done by four standing committees who address themselves to the betterment in methods of selection and guidance of the student engineer, the content of his college curriculum, the orientation of the graduate engineer in industry, and finally the procedures by which he is awarded professional recognition.

An important part of the report is the

lists of accredited undergraduate engineering curricula and programs of technical institutes. Also included are the "Canons of Ethics for Engineers," and the credo "Faith of the Engineer." A new feature of the report is an article "What is ECPD?" which tells of the history, organization and procedures of that group.

Copies of the report, which contains 47 pages, can be obtained from ECPD, 29 West 39th Street, New York, N. Y. Price per copy is 50 cents.

Mineral Wool Insulation

Industrial and commercial users of insulation, designers of heating equipment, and insulation contractors all will find in 36-page Standard, newly issued by the Department of Commerce, fresh and helpful guidance for applying mineral wool insulation to sheet metal and brick surfaces. Entitled "Mineral Wool Insulation for Heated Industrial Equipment," this Standard supersedes Commercial Standard CS1-17-44 and represents another advance in the continuing program of joint action between the Industrial Mineral Wool Institute and the National Bureau of Standards.

The Standard now covers also the loose, granulated and felted forms of mineral wool along with the blanket, block and industrial-batt forms on which some data have already been published. Twenty-six line drawings illustrate how to apply mineral wool to both flat and curved surfaces of all types encountered in high-temperature installations. Of particular value are the new drawings showing how to enclose mineral wool between metal sheets and between brick walls; how to support blanket insulation by clip-angles, or by impaling it on wires; and how to attach mineral wool with a stud gun, by bolts with heads welded to the metal surface, by sheet metal screws, or by hairpin wires.

Specification data include density, thermal conductivity, incombustibility and other physical information of value. A helpful table lists nine types of mineral wool, including pipe insulation and insulating cement. A second table gives thicknesses of standard and double-standard molded type pipe insulation for insulating standard steel pipe from 1/2 to 14 in. diameter.

Recommended minimum installation thicknesses to which the various forms of mineral wool should be applied when insulating equipment up to 1800 F are given in four additional tables.

Six line-drawings show cross-sections of mineral wool and supporting materials as applied to brick, steel, tanks, ducts and pipes. The use of insulating cement is outlined and illustrated both for indoor and outdoor applications. Seven pages are devoted to the application of blanket-type and molded-type insulation to pipe and pipe fittings. Included are eight line drawings illustrating application to large and small valves, flanges and fittings, in single and double layers.

Single copies of the Standard may be obtained, free of charge, from the Industrial Mineral Wool Institute, 441 Lexington Ave., New York 17, N. Y. Larger orders will be filled at 15 cents per copy.

A.S.T.M. Annual Meeting

A large number of technical papers and reports, including several symposiums, will be presented at the Fifty-Third Annual Meeting of the American Society for Testing Materials in Atlantic City throughout the week beginning June 26. During this week the Ninth Exhibit of Testing Apparatus and Related Equipment will be in progress. While the complete technical program is not yet developed there will be symposiums on the following subjects:

- Effect of Sigma Phase on the Properties of Metals at Elevated Temperatures
- Corrosion and Erosion of Gas Turbine Materials
- Sampling of Bulk Materials
- The Rôle of Non-Destructive Testing in the Economics of Production
- Methods of Testing Soils Under Triaxial Loading
- Identification and Classification of Soils

The 1950 Marburg Lecture is to be given by Dr. Wallace R. Brode, Associate Director of the National Bureau of Standards, who will speak on spectroscopy as allied to testing and analysis of materials.

Smoke Prevention Conference in Montreal

The Smoke Prevention Association of America will hold its next Annual Conference in Montreal, Canada, May 22 to 25, inclusive, with headquarters at the Mount Royal Hotel.

Following an address of welcome by Mayor Camillien Hode on Monday morning, there will be a symposium on air pollution, and in the afternoon committee reports will be submitted on "Emission of Solids from Chimneys" and "How Various Municipalities Control Air Pollution," by James Carter and Charles Gruber, respectively; also a paper by T. J. Barrett on "How Practical Does the Operating Engineer Find Smoke Ordinances."

At the Tuesday morning session, sponsored by the American Society of Heating and Ventilating Engineers, a paper will be presented by K. C. Richmond on "Public Relations in Air Pollution."

Tuesday afternoon session will be under the auspices of the American Industrial Hygiene Association and will include three papers as follows: "Health Implications of Air Pollution," by J. J. Bloomfield, of the U. S. Public Health Service; "Meteorological Techniques in Air Pollution Studies," by Merrill Eisenbud, of the Atomic Energy Commission; and "The Properties of Air Pollutants," by Dr. H. H. Schrenk of Mellon Institute.

The American Society of Mechanical Engineers will sponsor the Wednesday morning session at which will be presented papers on "Unsolved Problems in Air Pollution Control," by H. B. Lammers; and "Fly Ash Control" by J. L. Schuman and Phillip F. Best.

In the afternoon there will be a paper on "Fume and Toxic Gas Control from Manufacturing Processes," by W. I. Burt, and an inspection trip to the new unit yard and general repair shop of the Canadian Pacific Railway.

Thursday morning's session will be sponsored by the Institute of Power Engineers (Canada), with the program to be announced later; and in the afternoon the S.P.A.A. will hold its general business meeting.

New Egyptian Power Plant

A $5,337,000 order for a 45,000-kw steam-electric generating station to aid drainage and irrigation work along the Nile has been placed with the Westinghouse Electric International Company by Egypt's Ministry of Public Works. The order is believed to be the largest ever granted by the Egyptian government to a U. S. firm.

The new power station, to be located about 90 miles north of Cairo on the east branch of the Nile, will be the largest plant tying into the electrical network which supplies power to pumping stations in the Delta region. It will replace a number of small diesel power plants.

The new installation will contain three 15,000-kw turbine-generators, steam generating units, power transformers, piping, pumps, switchgear and substation apparatus. The boilers will be designed to burn Egyptian fuel oil, with provision for burning pulverized coal at a later date. Operation is scheduled for early in 1952.

Business Notes

Buell Engineering Company announces that it has acquired rights to manufacture and market in the United States the Swedish "SF" electrical dust precipitator which has long been produced by Svenska Fläktfabriken, a subsidiary of ASEA (the Swedish General Electric Company).

Fairfield Engineering Company of Marion, Ohio, has appointed E. D. Wolfram of 810 No. Milwaukee St., Milwaukee, Wisconsin, as its representative in eastern Wisconsin to handle portable coal-handling equipment.

L. J. Wing Mfg. Co., manufacturer of heating, ventilating and combustion equipment, and steam turbines, has consolidated its three separate factories in Newark, N. J., and general offices in New York City, into a single modern factory building at Linden, N. J. An Office at 154 W. 14th St., New York 11, N. Y., is being maintained to handle New York City sales.

Crosby Steam Gage & Valve Co. has moved its manufacturing facilities to Wrentham, Mass., where it has acquired a large modern plant of more than 100,000 sq ft floor space. Sales offices will be maintained in Boston, New York, Chicago, Dallas and Los Angeles. The **Ashton Valve Co.,** under the same ownership and management, has also moved to the Wrentham plant.

Kinney Manufacturing Co., Boston, manufacturer of rotary liquid pumps, high vacuum pumps and bituminous distributors, has moved its Chicago branch office from 59 E. Van Buren St. to 122 S. Michigan Ave.

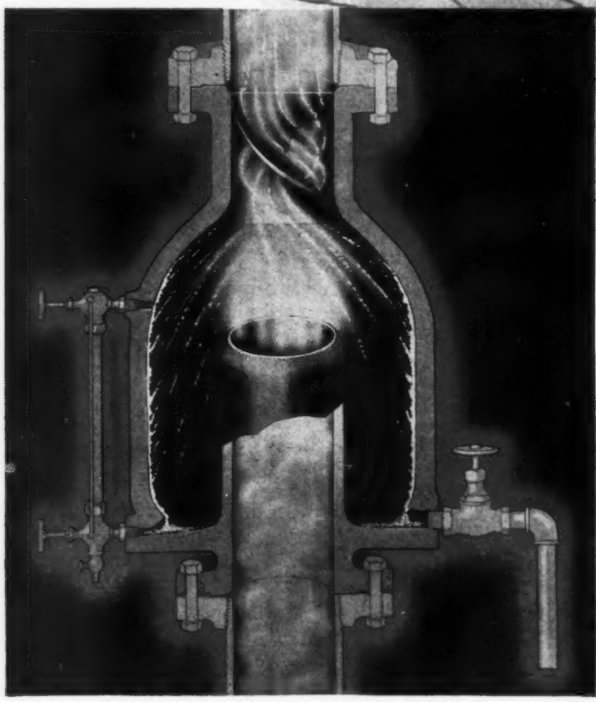
The Dampney Company of America, Hyde Park, Boston, has appointed R. E. Mundy Co. of Roanoke, Va., as sales representative in central Virginia and adjacent territory in West Virginia.

Gibbs & Hill, Inc., New York consulting engineers, have established a West Coast engineering office at 510 W. Sixth St., Los Angeles 14, Calif.

Flexitallic Gasket Co. has realigned its field organization by the appointment of three new agents and two distributors. The agents are Boiler Equipment Service Co., 686 Greenwood Ave., Atlanta, Ga.; Lane Machinery Co., St. Louis 1, Mo.; and Plant Equipment Co. of Minneapolis 15, Minn. The new distributors are The Moorlame Company of Tulsa, Okla., and Consultores Y Abastecedores Industriales S. A., of Mexico City.

Pacific Pumps, Inc., Huntington Park, Calif., has completed arrangements with Campagnie Generale de Construction de Locomotives—Batignolles Chatillon, for the manufacture and sale of its centrifugal pumps in France.

Swartwout helico-centrifugal separators assure 99% dry steam or better—with negligible pressure drop!



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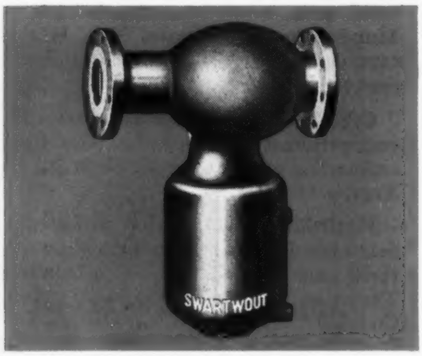

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